POWER PLANT ENGINEERING

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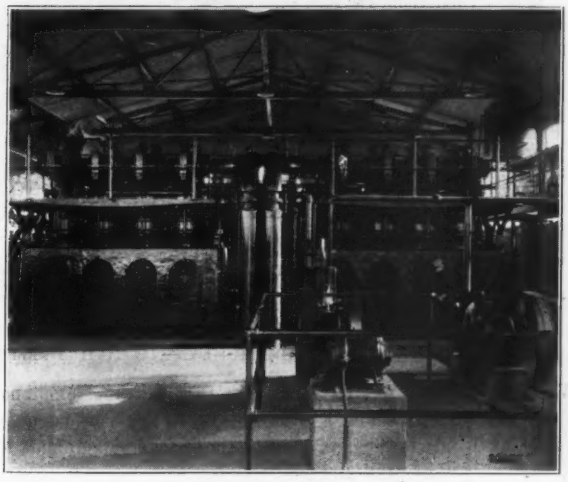
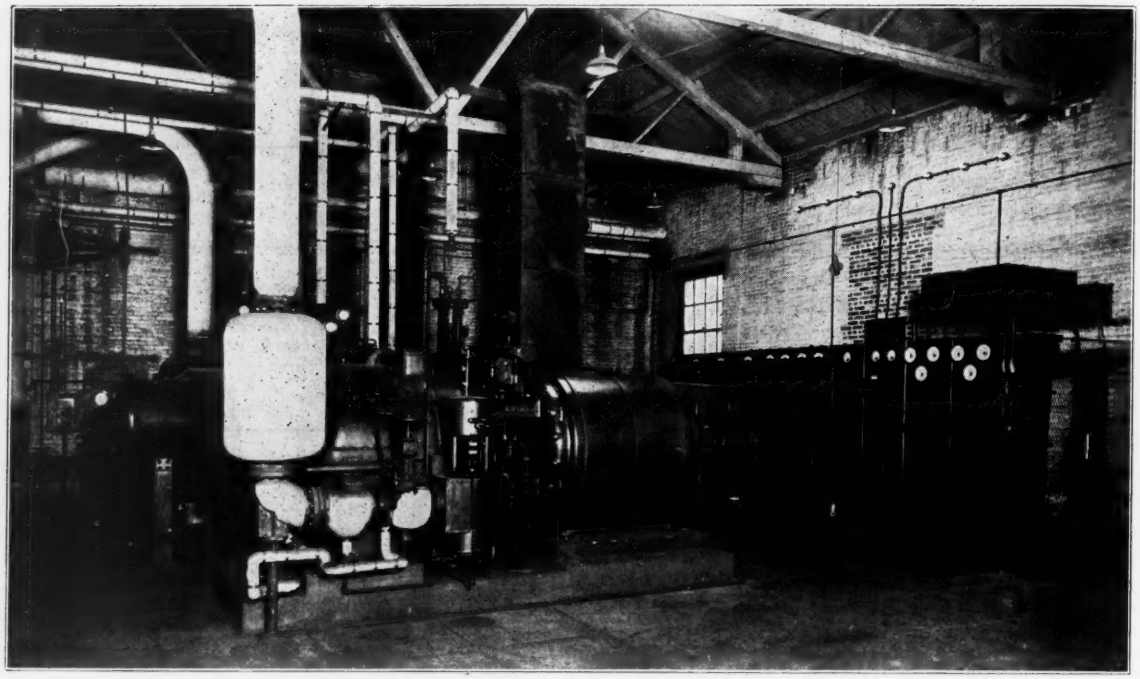


Plaster From Oil

THIS SOUNDS like going from wet to dry. And, as a matter of fact, there are several intermediate stages. The plaster is in the ground as a deposit of rock gypsum from which it is blasted. Then power comes into play to load, crush, convey, grind and calcine the rock. Electricity and compressed air are the media used for the tools and these are furnished by an oil engine plant, one of the engines being seen above. It is 800 hp. and there are three of them in the plant; also air compressors seen in the foreground. The engines, which drive a.c. generators to supply current to the 440-volt, 3-phase motors which run the machinery, are 8-cylinder, Ingersoll-Rand Diesels, solid injection type, using heavy fuel oil.

All which goes to show that whether bricks can be made without straw, plaster for pastures, houses or teeth moulds can be made with oil. It is simply a case of how it is used. The plant is that of the Pacific Portland Cement Co., Consolidated at Gerlach, Nev.

"WIRELESS" or radio, as it is commonly known, without question occupies the center of the world's stage today at least insofar as the tranmission of intelligence is concerned. When it becomes a question of transmitting energy, however, wireless methods haven't made much headway and we are still dependent upon the use of good metallic conductors. "Modern practice in power plant wiring," appearing in this issue by E. G. Sohlberg takes up one phase of the wiring problem in a way which should interest all power plant men.



Lumber Company Plant Burns Refuse with Coal

World's Largest Sawmill Cutting Mahogany Veneers Has a Power Plant Which Presents Many Features of Interest

WHEN A FIRM has been in continuous existence for almost a hundred years one can be quite certain of its commercial integrity and that its business methods are sound. Such a firm is Ichabod T. Williams and Sons of Carteret, N. J., established in 1838 and who maintain at the present time the largest sawmill in the world cutting mahogany veneers.

Until about three years ago this mill was located on Staten Island, N. Y., but then for various reasons, it was decided to move to Carteret, N. J., where an old manufacturing plant was available, the building of which could readily be adapted to lumber mill purposes. This was done and since that time operations have been shifted entirely to Carteret.

FIG. 1. EXTERIOR VIEW OF POWER PLANT SHOWING REFUSE CONVEYOR AND OVERHEAD STEAM LINE TO MILL

Among the various products of this mill are mahogany and walnut veneer and cedar stock, much of the latter going to the cigar box trade. As the production of veneer requires considerable power, both mechanical and as heat, it is evident that it is of considerable advantage to the owners to operate their own power plant.

As was the case with many of the mill buildings, the buildings housing the power producing equipment, with the exception of the boiler house which is new, were old mill buildings. The plant, which has now been in operation for about one year, consists of a turbine room, a boiler room, a pump room and a water treating room. The pump and water treating rooms are located between the boiler and turbine rooms.

Fuel

In any sawmill there is a considerable amount of wood waste available for use as fuel. At the time that this plant was built it was thought that sufficient refuse would be available to supply all of the fuel requirements of the boiler house. Since it has been in operation, however, the load has gradually increased and the mill has not produced enough refuse to eliminate entirely the use of coal. Both coal and wood refuse are burned at the present time.

The original plan of using wood refuse entirely is responsible for the fact that relatively few instruments were installed particularly in the boiler room. It was not deemed necessary to strive for high efficiency where plenty of waste fuel was available. Now, however, that coal is being used, it is highly important that an accurate check be kept on the economy of operation, and a good collection of instruments is gradually being installed.

Of the five boilers installed, three are old units moved over from the old plant on Staten Island and two are new. The latter are Babcock and Wilcox Co. boilers rated at 440 hp. Of the remaining boilers, two are Rust units of 400 hp. rating and one is a 230-hp. Heine boiler. These five units are installed in one row and with the exception of the Heine unit are fitted with Dutch oven type of furnaces to facilitate the burning of wood refuse.

Wood refuse which consists of hogged fuel and sawdust is conveyed from the mill buildings to the boiler house on overhead mechanical conveyors as shown in Fig. 1 and is allowed to fall by gravity into the tops of the Dutch oven furnaces, directly onto the grates. Coal is fired by hand through furnace doors in the front of the Dutch ovens.

All boilers are fitted with S-C feed water regulators and Diamond soot blowers. Blowoff valves are the Everlasting in combination with B. and W. valves on the Heine and B. and W. boilers and with Yarnall valves on the Rust boilers. A 150-ft. radial brick stack supplies the necessary draft above the fuel bed while Coppus Vano blowers installed on each furnace provide forced draft under the grates.

The speed of the forced draft fans is controlled by the steam pressure in the boilers through the agency of a Foster regulator. The matter of securing a satisfactory means of automatic control for the fans was one which required considerable experimentation but the present system functions very well as may be seen from the steam pressure chart reproduced in Fig. 5. From this chart it is evident that the regulator is in action only between 8 a.m. and 5 p.m. During the night the mill closes down and the boilers are banked. The steam pressure during the day is easily kept within 5 lb. of the normal pressure, 150 lb.

Feed water for the boilers is city water and is treated by the Cochrane hot process softening system using lime and soda ash as the treating agents. In this system the water is heated to a temperature of 205 deg. F. or higher and is then mixed with the reagent. The water is then passed into a sedimentation tank where the scale forming materials in the water are precipitated to the bottom.

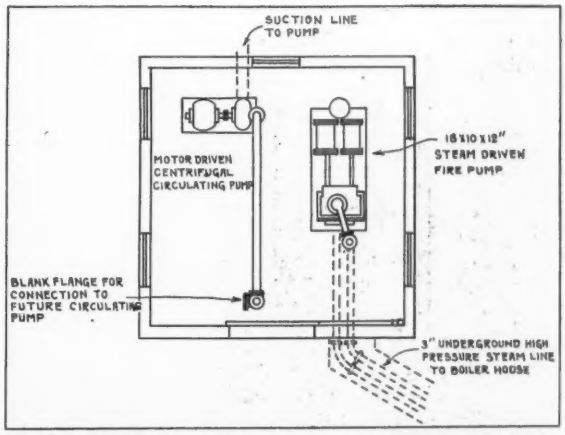

SUCTION LINE TO PUMP
MOTOR DRIVEN CENTRIFUGAL CIRCULATING PUMP
18 X 10 X 12" STEAM DRIVEN FIRE PUMP
BLANK FLANGE FOR CONNECTION TO FUTURE CIRCULATING PUMP
3" UNDERGROUND HIGH PRESSURE STEAM LINE TO BOILER HOUSE

FIG. 3. DIAGRAM SHOWING ARRANGEMENT OF EQUIPMENT IN PUMP HOUSE

The softener is installed in a separate room between the boiler room and the turbine room as shown in Fig. 3. It is a compact unit and the pumps and agitator connected with it are driven by a 3-hp. General Electric induction motor.

The treating room also contains two other pumps, one of which is a booster pump used for increasing the city water pressure which sometimes falls low, while the other is used for turbining the boilers and for washing down purposes. Both of these units are Blake-Knowles, formerly used at the old plant.

Feed water is heated in a Cochrane open heater installed outside of the boiler house. This heater, naturally, is provided with heavy insulation and in itself gives no trouble in winter time. Some difficulty, however, has been experienced with the connections and valves to the heater freezing, and it is the chief engineer's plan to have the heater enclosed before next winter.

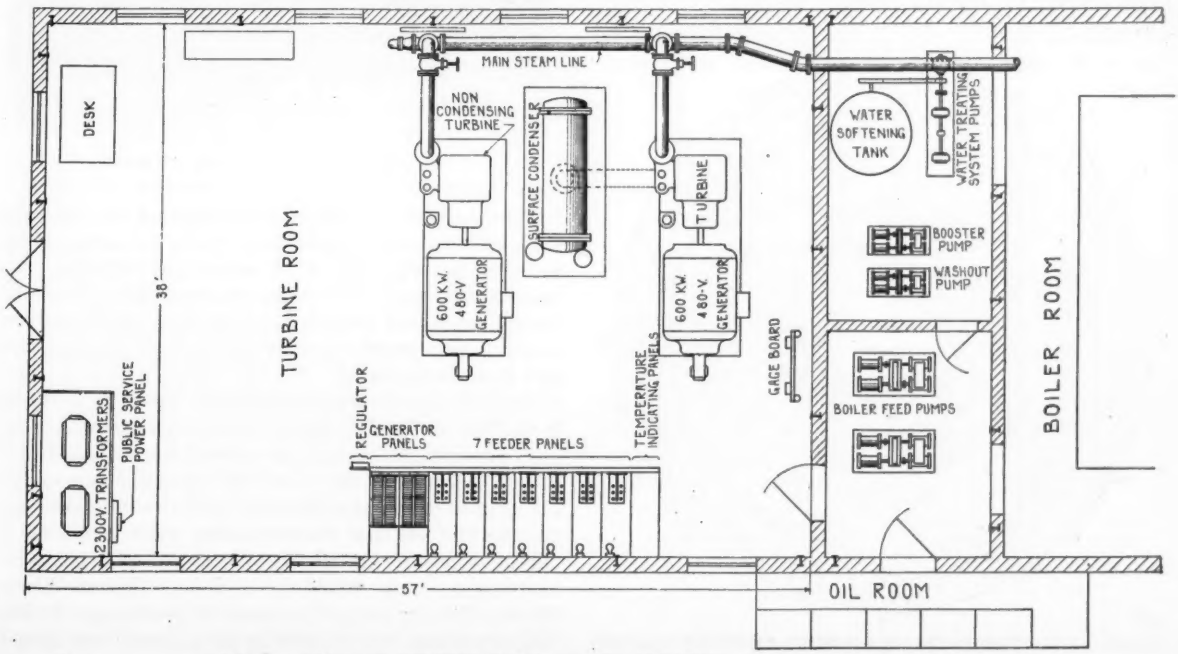


FIG. 2. PLAN OF TURBINE ROOM, WATER TREATING ROOM AND PUMP ROOM

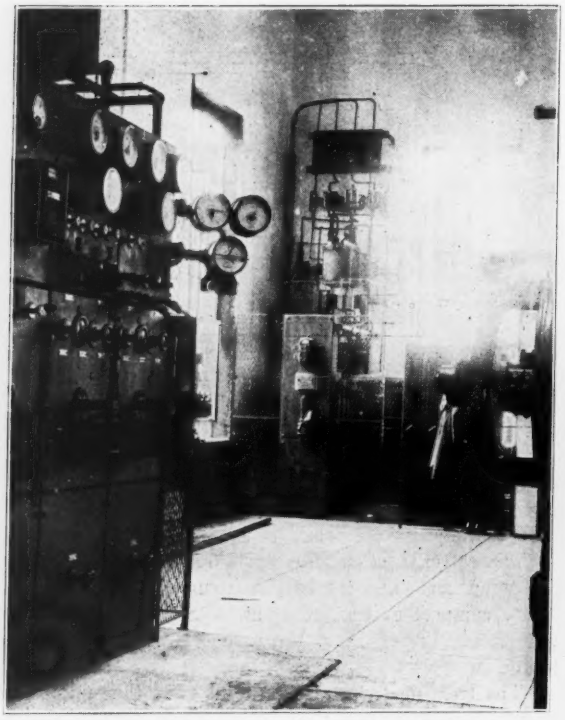


FIG. 4. TRANSFORMERS AND SWITCHING EQUIPMENT FOR HANDLING CURRENT FROM PUBLIC SERVICE CO.

For boiler feed purposes two pumps are provided. These, as has been stated previously, are installed in a pump room adjacent to the boiler room and are both Blake-Knowles units, size 10 by 6 by 10 in., fitted with S-C back pressure regulators.

Steam Requirements

The steam requirements in a mill of this type are large. In the process of cutting veneer it is necessary either to soak the logs in a bath of hot water or to steam them for an extended period of time. In most of this work low pressure steam is used but for certain purposes high pressure steam is necessary. In addition to that used in soaking and steaming the logs, steam is required to operate the "loaders," "kickers," "niggers" and "dogs." These devices are heavy users of steam and as they are located in a building some distance from the power plant, are supplied with steam at 150 lb. pressure by a 6-in. overhead line. This line is carried on the same wooden supports which carry the mechanical fuel conveyor. It is insulated with double standard 85 per cent magnesia insulation and is provided with two expansion loops. At the present time this steam line is handling 275 hp. continuously.

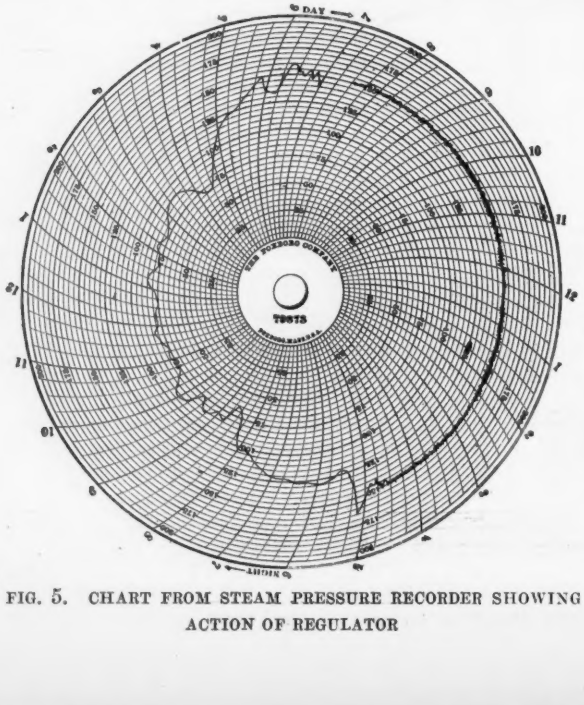


FIG. 5. CHART FROM STEAM PRESSURE RECORDER SHOWING ACTION OF REGULATOR

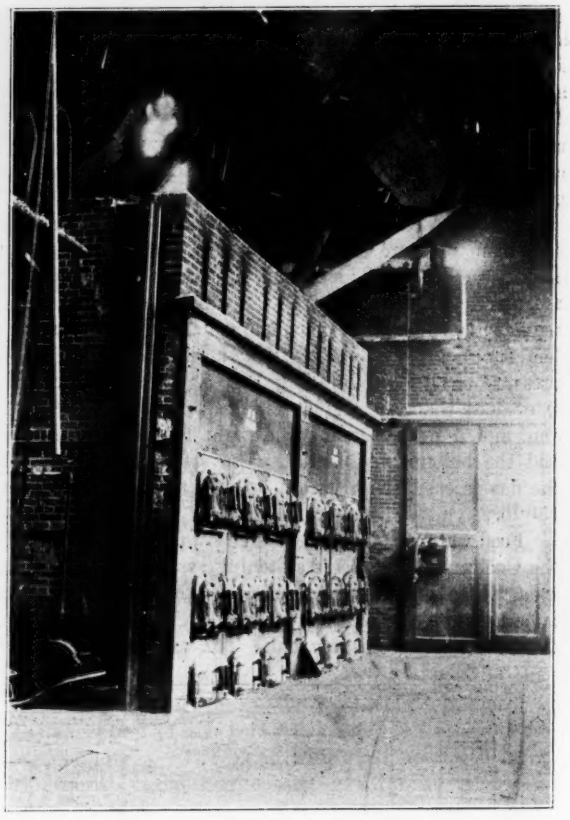


FIG. 6. TWO OF THE FIVE BOILERS

There are three cedar tanks for soaking the cedar logs. Each of these has a capacity of 27,000 gal. of water and are provided with 225 ft. of submerged radiation. For steaming the logs five tanks are provided. These are merely large steel tanks with covers into which low pressure steam is turned. For certain kinds of logs high pressure steam is necessary.

In addition to the overhead high pressure steam line to the "loaders" and "kickers," there is a 3-in. underground high pressure line running to a pump house located about 500 ft. from the boiler room. This pump house contains the main fire pump supplying the sprinkler system throughout the mill and also the circulating water pump for the surface condenser in the turbine room. The latter is a centrifugal pump driven by a 20-hp. Western Electric Motor. The fire pump is a steam driven George F. Blake Mfg. Co. pump, size 18 by 10 by 12 in., which was formerly installed in the Staten Island plant. At one time this

pump saved the plant from total destruction by fire. At the present mill, all buildings with the exception of the power house are equipped with automatic sprinklers. This is by necessity a dry system, since many of the buildings are not heated and trouble would be encountered by freezing in winter time if the wet sprinkler system were used.

The Turbine Room

During the day, all electricity used in the mill is generated at the plant; but at night, when the load is light and when the requirements for exhaust steam are low, power is purchased from the public service company.

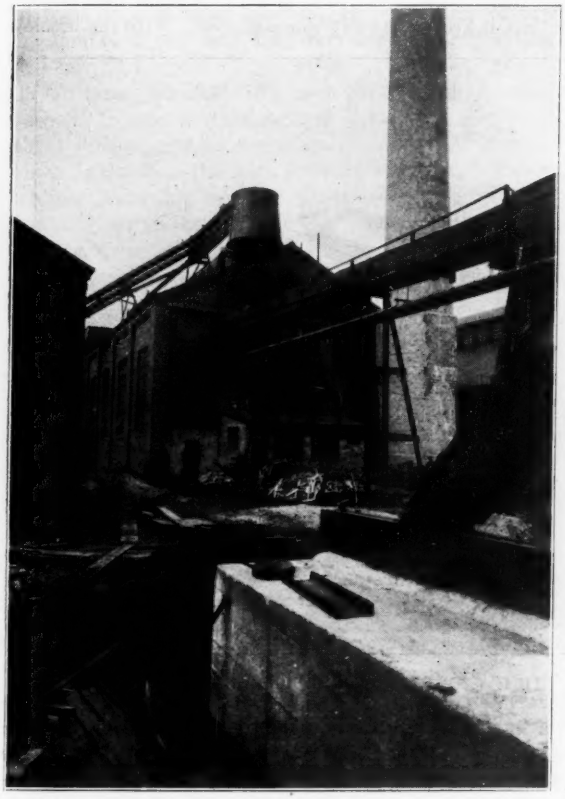


FIG. 7. CLOSE-UP VIEW OF BOILER ROOM SHOWING SAWDUST COLLECTOR AND FUEL CONVEYOR

Two turbo-generators are installed, both 3-stage General Electric Co. machines, operating at 3600 r.p.m. on a steam pressure of 150 lb. and rated at 600 kw. One operates non-condensing while the other is of the condenser bleeder type. The generators of these units are rated at 750 kv.a., 80 per cent power factor, 60 cycles, 480 v., 902 amp. per terminal, with direct connected exciters.

For the condensing unit, a C. H. Wheeler surface condenser is installed. An interesting feature in connection with this installation of this condenser is that is it one of the few surface condensers installed in this district. This plant is located on that body of water between New Jersey and Staten Island, N. Y., known as Arthur Kill, in the heart of one of the most intensive industrial districts in the United States. The entire river is lined with ship yards, chemical plants, fertilizer works, oil refineries, leather, tar, coal, lumber and asphalt works; in fact, almost every type of manufacturing plant can be found here. The water, to begin with, is not fresh (it is sea water) and because of the enormous quantities of industrial wastes

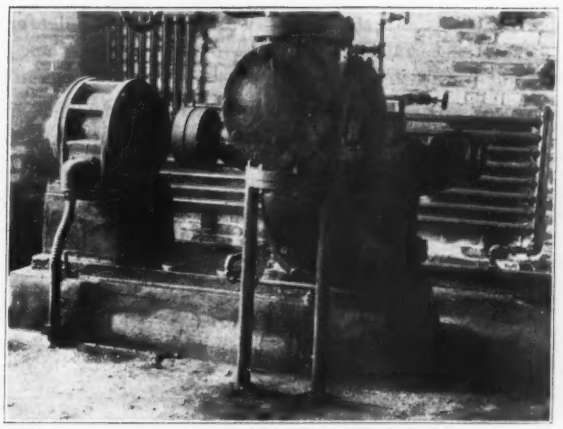


FIG. 8. THIS CIRCULATING PUMP FOR THE CONDENSER IS LOCATED IN THE PUMP HOUSE ABOUT 500 FT. FROM THE POWER HOUSE

and refuse of all kinds discharged into it, it is fit for anything but good surface condenser practice. The result of this condition is that surface condensers using this water for circulating purposes are almost entirely unknown; this, in fact, is one of the first to be installed. As a matter of fact, it was more or less of an experiment, and its performance is being regarded with considerable interest.

Although trouble was encountered with corrosion and pitting at first, the unit is performing satisfactorily at the present time. The engineer in charge has tried various metals for condenser tubes and is of the opinion that the tubes installed at present will give at least 4 yr. of service before it becomes necessary to renew. The tubes are cleaned once every two weeks by forcing through rubber plugs under air or water pressure. This method gives good satisfaction.

Another point of interest in the installation of this condenser although not by any means novel, is the fact that it is installed on the same level with the turbines. This was necessary because of the lack of a basement underneath the power plant. A Ludlow gate valve is pro-

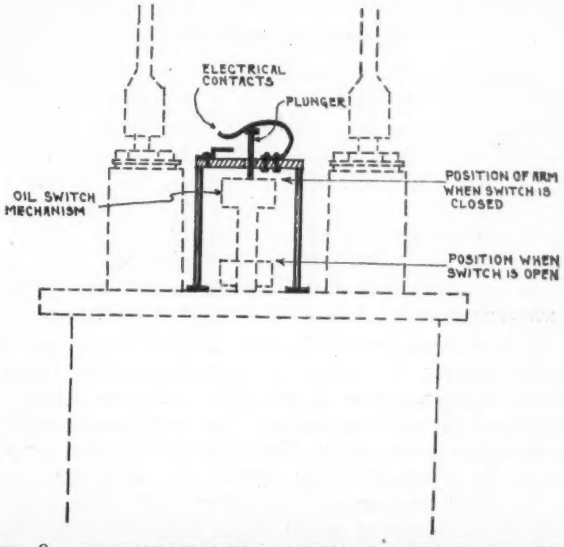


FIG. 9. DIAGRAM SHOWING AUXILIARY CONTACTS ON GENERATOR BREAKERS FOR CUTTING IN OR OUT THE PUBLIC SERVICE CURRENT

vided between the turbine exhaust line and the condenser. Expansion and contraction stresses that might be set up in the condenser or piping due to temperature conditions are avoided by the use of Wainwright expansion joints installed in the exhaust line and the circulating water discharge line where they connect to the condenser.

The circulating pump as stated previously is not located near the condenser as is usually the case, but is installed in the pump house some 500 ft. from the power plant.

Piping

The piping layout in this plant is simple and direct. All steam piping is carried overhead and covered with magnesia insulation. The main steam lines to the turbine are carried along one wall with headers branching off to the turbines. A separator is provided in each turbine header before it enters the turbine.

FIG. 10. A PORTION OF THE LOG POND AT THE I. T. WILLIAMS AND SONS PLANT

Electrical Features

Current for all purposes is generated and distributed at 480 v. The switchboard consists of 10 panels divided as follows: two generator panels, seven feeder panels and one temperature indicating panel for showing the temperature of the generator windings. Besides these there is also a small panel at one end carrying a Westinghouse Type A-B-3 voltage regulator with a swinging bracket containing a.c. and d.c. voltmeters and a synchroscope. The oil circuit breakers are all of the hand operated type with the mechanism mounted directly on the rear of the panels.

A novel arrangement has been devised for indicating to the operator the opening of any of the seven feeder circuit breakers. Seven incandescent lamps are mounted on the wall above the switchboard, each lamp corresponding to one of the feeder panels. Each lamp is connected across one of the out-going feeder circuits so that in case one of the feeder breakers trips out (which they often do because of the irregular nature of the load), the lamp corresponding to that circuit will be dark. Normally with all feeder circuits alive the lamps are lighted.

At night, the turbo generators are shut down and electric power is obtained from the public service company. For this purpose a bank of 2300-v. transformers are installed in one corner of the turbine room as indicated on the plan, together with the necessary meters and control panels.

To preclude any interruption of service when switching over from public service to house service, a set of auxiliary contacts are mounted on each of the main generator circuit breakers which automatically cut in the public service supply when the generator breakers are opened. This arrangement is shown in Fig. 9. A plunger is so placed that when the circuit breaker arm is up, that is, in the "closed" position, it keeps the relay contacts open. With the breaker arm in the "open" position the plunger falls and the contacts close, operating the relay which in turn cuts in the public service power.

The minimum power rate for public service current is $200 a month. In winter this is just about what is actually used, but in summer the current consumed is considerably less than that charged for with the minimum rate. It is possible, therefore, that a small turbo-generator may be installed which is sufficiently large to carry the night load but which will run idle during the day, the generator being utilized as a synchronous motor to improve the power factor which is somewhat low.

This low power factor is not only due to the fact that induction motors are used throughout the entire mill but also because the ratio of minimum to full load of the machines in the mill is relatively high. The motors driving the machines must have considerable reserve capacity and as a consequence, they operate under load for a good part of the time.

Conclusion

In concluding this description we wish to extend credit to the officials of Ichabod T. Williams and Sons for courtesies extended in the matter of securing data and to Mr. Johnson, chief engineer for valuable assistance rendered while visiting the plant.

The Regenerative or Stage Bleeding Cycle

REHEATING OF THE FEED WATER IN A NUMBER OF STAGES HAS A DECIDED EFFECT UPON ECONOMY. BY JOSEPH RAZEK*

IT IS natural that the apparently permanent increase in the price of fuel since the war should have provided a powerful incentive for power plant designers and operators to attain the highest possible economies in their plants. Many improvements and refinements, which a few years ago were considered of purely academic interest, now can be financially justified, even though the saving may be only a fraction of a per cent. The steadily increasing size of the individual stations has brought about a proportionate increase in quantities handled, and a saving of even a fraction of a per cent may represent a large saving in money.

Turbine manufacturers have steadily improved their designs, so that today their best units have efficiencies of about 80 per cent of the theoretically possible ideal turbine. Leakage in the high pressure stages, and the excess friction losses due to high velocities and moisture in the low pressure stages will probably prevent these efficiencies from being much increased. Consequently the power plant designer was forced to look for improvements to the other parts of his plant—the boiler room and the feed water system. In the former, the use of pulverized fuel, air preheaters and, more recently, the radiant heat side wall heating surface, have brought about a considerable improvement in economy. In the feed water system, the adoption of bleeder steam heating of the feed water has been an outstanding feature of most of the large power stations recently built or in course of construction. It is the purpose of this article to discuss the main features of bleeder heating of feed water.

"Bleeder heating," "extraction heating," "stage heating" or "regenerative heating" are all names for the practice of heating the feed water in steps or stages by means of steam extracted or bled from one or more stages of the main unit. Extracting steam from the main unit and imparting the heat of this steam to the feed water really changes the cycle on which the station is operating from the Rankine cycle to the "Regenerative cycle."

The regenerative cycle is by no means new. It seems to have been hinted at by John Bourne, who, about 70 yr. ago, suggested the use of a "snifting" valve on the cylinder of a steam engine, to open before release, and admit steam to a feed water heater. Weir applied the cycle to a compound engine, taking the steam from the low pressure receiver of a triple expansion engine. Before 1900, large pumping engines were fitted to extract steam from the receivers for heating the feed water. The celebrated Wildwood engine, of which a complete test was reported to the A. S. M. E. by R. H. Thurston in 1899, used four stages of heating.

At about that time, the turbine entered the field. The lower first cost, due to the greatly reduced size and weight of the turbine as compared to the reciprocating engine, made the turbine a formidable competitor of the engine, in spite of the fact that the water rate of the turbine was above that of the engine. The next two decades saw the turbine develop from small, relatively inefficient units of 1000 kw. to giants of 60,000 kw. and the water rate drop to values below that of the engines. The relatively low cost of fuel, and the rapid development of the turbine itself during that time, made economical operation possible, without such refinements as bleeder heating. But today the high cost of fuel, and the increasing size of units, together with the fact that the turbines themselves are near their peak of development with existing pressures and temperatures, forces the adoption of the various improvements, one of the most important of which is bleeder heating.

Large steam turbines are always multi-stage units in which the pressure and temperature drop progressively from stage to stage. There are as many gradations of pressure as there are stages. By suitably altering the design of the unit, it is possible to extract steam from the unit at a number of points between the first and last stage. This steam will be at a pressure somewhere between the

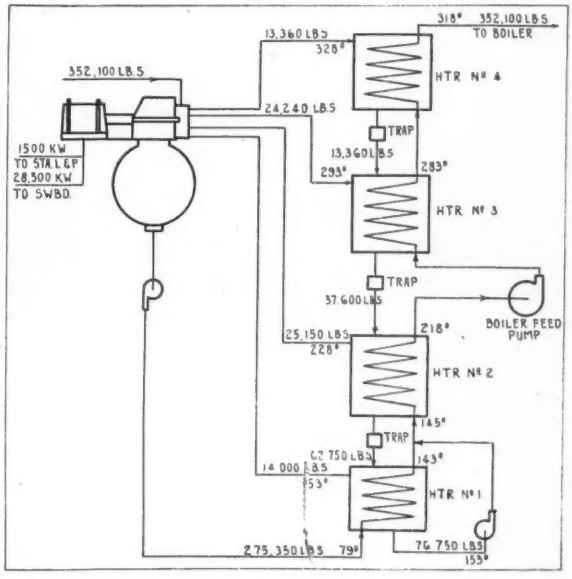


FIG. 1. LAYOUT FOR STAGE REHEATING. FEED WATER IS HEATED IN 4 STAGES

throttle pressure and condenser pressure, depending on the location of the extraction point. The nearer a particular extraction point is to the first stage, the higher will be the temperature and pressure of the steam.

This extracted steam can be used for heating the condensate of the main unit which is used as boiler feed. The condensate leaves the condenser at a relatively low temperature, nearly the saturation temperature corresponding to the vacuum in the condenser. The condensate is first heated by steam bled or extracted from a low pressure stage, up to within a few degrees of the saturation temperature of the steam. Then it is admitted to another heater and heated by steam bled from a higher pressure stage. This can continue progressively until the water is heated to any desired temperature, theoretically up to boiler saturation temperature. With steam bled from every stage, and as many levels of heating as there are stages, the boiler feed would be heated up to boiler saturation temperature,

*Instructor in Mechanical Engineering, Towne Scientific School, University of Pennsylvania.

and the plant would be operating very closely to the regenerative cycle. It can be proved that the regenerative cycle is equal in efficiency to the ideal Carnot cycle.

Practical considerations of space requirements and investment, however, limit the number of stages in which the feed water is heated. Two or three steps are used in most plants, with a few designed for four levels.

The steam extracted at any particular stage has had an opportunity to give up part of its energy in the form of work while in the main turbine. Practically all the energy not converted into work in the turbine is returned to the boiler in the feed water; consequently, that portion of the steam which is extracted is used at an efficiency of nearly 100 per cent. The steam which remains in the turbine throughout the whole expansion to the condenser pressure must give up nearly all the energy not converted into work, to the condenser circulating water, and that energy is lost down the river.

Since the extracted steam has not given up as much energy in the form of work as the steam remaining throughout the expansion, more steam must be admitted

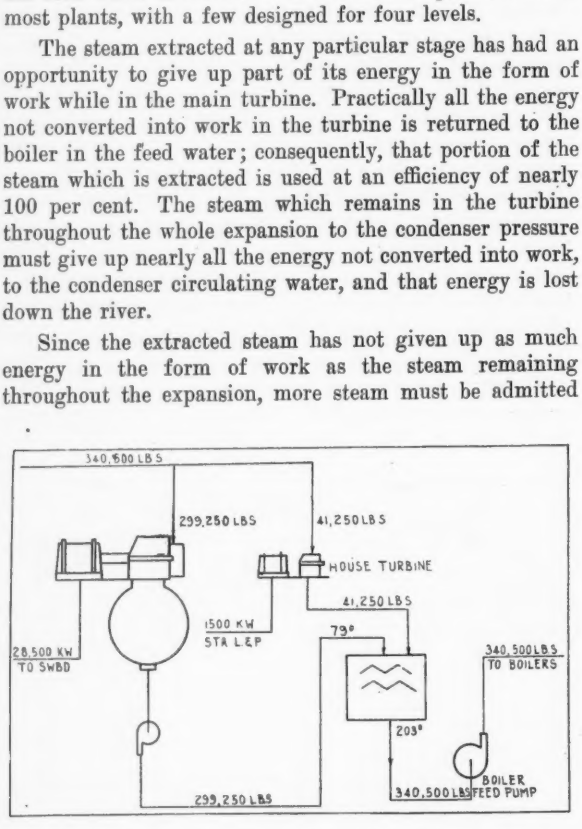


FIG. 2. LAYOUT FOR RANKINE CYCLE OPERATION

to the throttle for a given output than is required when the unit is operating on the non-expansion or Rankine cycle. But the increase in throttle steam will not be as much as the amount extracted and so less steam remains in the turbine to be exhausted to the condenser. About 56 per cent of the energy in the steam supplied to the throttle is rejected to the condenser circulating water, and any reduction in the amount of steam exhausted to the condenser for a given output, will represent a saving proportional to that reduction.

Relation of Stage Heating to Operation of Auxiliaries

Stage heating is intimately connected with the question of auxiliaries. In every steam power plant, there are a number of auxiliary machines, such as circulating pumps, boiler feed pumps, draft fans, exciters, and others. The power to drive these, together with that for station lighting, is grouped under one item, as "station light and power," and amounts to about 5 per cent of the generator capacity. Interruption in the operation of the auxiliaries cannot be tolerated, since such interruption would probably shut down the station completely. In order to obtain reliability of operation, in the smaller and more or less isolated systems, it was considered necessary to drive the auxiliaries by direct-connected, steam-driven units. If some were electrically driven, the power was generally supplied by an independent house turbine.

The small auxiliary turbines, or the larger house turbines, were operated non-condensing, at about atmospheric back pressure, and their exhaust used to heat the condensate of the main unit on its way to the boiler. Thus the condensate was heated to about 210 deg. F. All the heat supplied in the auxiliary steam, was either converted into useful work, or returned to the boiler with the feed water. But as the initial pressure and superheat of the steam supply increased, the small auxiliary units could extract only a small portion of the energy from each pound of steam in the form of useful work, with the result that the exhaust was highly superheated and had a high heat content, but was only at atmospheric pressure. In summer the vacuum dropped, due to the higher circulating water temperature, and the condensate left the condenser at a correspondingly higher temperature. The condensate could then absorb only a portion of the high heat content auxiliary exhaust, and the excess had to be wasted to the atmosphere. To avoid this, some auxiliaries were motor driven with power supplied from the main generator, and only enough auxiliaries driven by steam to supply the proper amount of exhaust for feed heating. If a separate house turbine was used to supply the auxiliary power, this unit could be operated condensing, with the main unit condensate as circulating water for the house turbine condenser. The greater efficiency of the house turbine as compared to the smaller auxiliary units, made it possible to supply the required auxiliary power with less steam, consequently less exhaust had to be absorbed by the feed water.

The main unit is the most efficient in the plant. It extracts about 80 per cent of the energy theoretically possible of extraction in the form of work, as compared to about 50 per cent for the smaller auxiliaries. The main unit should therefore supply all the power required, even the auxiliary power. It is true, the total heat content of the auxiliary exhaust can be absorbed by the condensate, provided there is enough of it and it is sufficiently cold, but there is a loss in "heat head" in absorbing the high temperature steam by the cold water. The auxiliary units rejected their waste heat at too high a temperature. Now, Carnot proved that the most efficient heat engine should receive all its heat at the maximum temperature and reject all the heat not converted into work, at the lowest temperature. The main unit nearly fulfills the last requirement; it expands its steam down to condenser pressure, and the temperature is only a few degrees above the rejection temperature, which is the temperature of the circulating water.

If the auxiliary power is supplied by the main unit, however, there will be no steam available for heating the cold condensate and additional heat will have to be supplied to the feed water in the boiler system. Besides, the admission of cold water to the highly heated boiler structure might set up serious temperature strains. By heating the condensate with steam bled from the main unit, it will be possible to do the heating even more efficiently than was possible when the heating was done by auxiliary exhaust. Since extracted steam at any pressure up to throttle pressure can be obtained by bleeding the proper stage, the feed can be heated to any temperature, up to boiler saturation temperature. This will reduce the amount of heat which must be added to the feed in the boiler system.

Use of Auxiliary Source of Power

There is some loss in reliability when the auxiliaries are driven with power from the main unit, but in a large inter-connected system, the probability of complete electrical failure is slight. Sometimes, to isolate the source of auxiliary power, a separate generator is coupled to the main turbine. In this way the auxiliary power is still supplied by the main turbine, but the auxiliary power will not be seriously interrupted by electrical trouble in the main generator. In any case, some of the most important auxiliaries can be supplied with duplex drives, ready to switch over to steam operation, in case of emergency. An independent turbo-generator can be kept in readiness to pick up the auxiliary load.

To illustrate the foregoing discussion, an example has been worked out. Heat balances of a 30,000-kw. unit operating respectively on the regenerative cycle and the Rankine cycle are compared. In the former case, the unit is arranged for heating the feed water in four stages, as shown in Fig. 1. The pressures at the bleed points are respectively, 4, 20, 60, and 100 lb. per sq. in., absolute. The temperatures given in the figure are the saturation temperatures corresponding to these pressures. Assuming a terminal temperature difference of 10 deg. in every case, the feed water is heated from 79 deg. to 318 deg. The condensate from each heater is trapped into the next lower heater, except in the case of the first level heater, whose condensate is pumped into the main feed water circulation. The boiler feed pump is placed between the second and third level heaters. This arrangement of heaters is known as the "cascade" arrangement. An actual installation would be somewhat more complicated by an evaporater system, surge and storage tanks, and bypasses, to allow the isolation of any one heater without shutting down the system.

The same unit, arranged for operating on the Rankine cycle, is shown in Fig. 2. The main unit condensate is heated in an open heater, which receives steam from an auxiliary house turbine.

Comparative results are given in the table. The data for the regenerative cycle are given in the first column and those for the Rankine cycle, in the second column. In the former case, the main unit is operating at 30,000 kw. of which 5 per cent or 1500 kw. must be used for station light and power, leaving 28,500 kw. available at the switchboard. In the case of the Rankine cycle, the auxiliary power is supplied by the house turbine, and the total main unit output is available at the switchboard. Radiation losses were neglected in making the computations, since they do not seriously affect the comparison between the cycles. All the weights are given in pounds per hour.

It will be seen that in the case of the regenerative cycle, the weight of steam to be supplied by the boiler increases 11,600 lb. per hr. over the Rankine cycle requirement, but the weight of steam to be exhausted to the condenser is 23,900 lb. per hr. less for the regenerative cycle.

In the case of the Rankine cycle, the feed is heated to 203 deg. by the exhaust of the house turbine, whereas in the case of the regenerative cycle, the feed enters the boiler system at 318 deg. The boiler system must supply 318 — 203 or 115 B.t.u. less to each pound of feed. Thus, in spite of the increased water rate of the regenerative cycle, the heat rate will be 12,812 B.t.u./kw-hr., as compared to 13,788, B.t.u./kw-hr. for the Rankine cycle, a saving of 7.1 per cent. Boiler efficiencies are neglected, since they can be kept approximately equal in both cases, as will be explained later.

In the given example, 9.66 lb. per kw-hr. are exhausted to the condenser, in the case of the regenerative cycle, as against 10.5 lb. per kw-hr. for the Rankine cycle, a reduction of 8 per cent. The loss of energy to the circulating water is reduced in the same ratio. Looking at these figures in another way, of the 12.35 lb. per kw-hr. required for the regenerative cycle, 2.69 lb. are used at an efficiency of practically 100 per cent. The main unit converts some of the heat of this 2.69 lb. into work, and all the rest of it is returned to the boiler system in the feed water. The remaining 9.66 lb. are exhausted to the condenser. In the case of the Rankine cycle, of the 11.95 lb.

HEAT BALANCE OF A 30,000-KW. TURBINE

	Regenerative Cycle	Rankine Cycle
1. Load on Main unit, kw.	30,000	28,500
2. Throttle pressure, lb. per sq. in. abs.	360	360
3. Superheat, deg. F.	200	200
4. Back pressure, Ins. Merc.	1	1
5. Condensate temperature, deg. F.	79	79
6. Water rate, non-extracting, lb. per kw-hr.	10.5	10.5
7. Station light and power, 5 per cent, kw.	1,500	1,500
8. Water rate, house turbine, lb. per kw-hr.		27.5
9. Weight steam to main unit, lb. per hr.	352,100	299,250
10. Weight steam to house turbine, lb. per hr.		41,250
11. Weight steam required, total lb. per hr.	352,100	340,500
12. Weight steam to htr. No. 1, lb. per hr.	14,000	.....
Weight steam to htr. No. 2, lb. per hr.	25,150	.....
Weight steam to htr. No. 3, lb. per hr.	24,240	.....
Weight steam to htr. No. 4, lb. per hr.	13,360	.....
13. Weight steam returned in feed, lb. per hr.	76,750	41,250
14. Weight steam exhausted to Condenser.	275,350	299,250
15. Final feed water temp., deg. F.	318	203
16. Water rate, lb. per kw-hr. at swbd.	12.35	11.95
17. Heat rate, b.t.u. per kw-hr. at swbd.	12,812	13,788
18. Weight condensate, lb. per kw-hr. at swbd.	9.66	10.5
19. Weight steam returned in feed, lb. per kw-hr.	2.69	1.45
20. Thermal efficiency based on heat of steam at throttle, per cent.	26.65	24.77

per kw-hr., only 1.45 lb. are returned to the feed, leaving 10.5 lb. to be exhausted to the condenser.

Advantages of Regenerative Cycle

Summarizing, the regenerative cycle offers numerous advantages over the Rankine cycle. The feed water can be heated as closely to the boiler saturation temperature as desired. The heat rejected to the condenser is reduced by decreasing the weight of steam to be exhausted to it. Providing sufficiently large passages in the last stages of a turbine has always been difficult and turbine designers have been forced to accept high velocities, with the attendant friction losses, in order to keep the blade lengths within reasonable limits. By bleeding steam from the unit in the earlier stages, the amount of steam to be handled in the last stages is reduced, thereby reducing the steam velocity, for a given size passage. In the lower stage bleed points, some moisture will be removed with the extracted steam, which will also tend to reduce the friction loss, and diminish erosion of the blades. The reduced amount of exhaust will make possible either the use of a slightly smaller condenser, or one less heavily loaded.

Balanced against these advantages, there are some practical considerations which must be noticed. By eliminating the small auxiliary turbines, there is some loss in reliability because a shutdown of the main unit, removes that source of auxiliary power. As mentioned before, some steam driven auxiliaries will be needed for emergency and start-

ing purposes. By heating the feed with the bled steam, to a high temperature, the work left for an economizer is considerably reduced, with the result that the flue gases would leave at too high a temperature. Much of the gain resulting from the use of the regenerative cycle would be lost if the stack loss were increased. By the use of the air preheater to heat the combustion air on its way to the furnace, as much heat can be recovered from the flue gases, as could be recovered in the economizer, and the stack loss will remain unchanged. The boiler efficiency should be the same for both cycles.

There are more pieces of apparatus intimately connected with the main unit making operation somewhat more complex. This is hardly a serious objection, since bypasses can be arranged to cut out temporarily any part of the heating system. Finally, the question of increased investment and maintenance is brought up. The several heaters should not require more maintenance than was required by the numerous small turbines. Fluids on both sides of the heating surface are pure and no difficulty should be experienced with fouling or corrosion. At least one of the heaters can be fitted for air elimination. The heaters are simple pieces of apparatus, and their cost should represent only a small portion of the total station cost. The available capacity of a turbine operating on the regenerative cycle is slightly less than that operating on the Rankine cycle, owing to the auxiliary power requirement, which is supplied by the main unit in the former case. The greater economy should outweigh that objection.

The practice of stage heating has become firmly established, as proved by the fact that the largest and newest central stations are using it successfully and its adoption by all plants where high economy is required, can be expected.

Development of Pulverized Coal*

HISTORICAL OUTLINE SHOWING THE EXPERIENCE OF NEARLY A CENTURY OF RESEARCH. BY H. W. BROOKS[1]

FIRST-KNOWN attempts to use coal in powdered form were made in the early years of the nineteenth century, but unfortunately no records of these experiments are extant. The oldest literature on the subject is a British patent No. 6207, granted in 1831 to John Samuel Dawes, Ironmaster of Bromford in the County of Stafford. Subsequent patents were issued in 1846, 1854 and 1856 covering the art of pulverized-coal firing, but all developments thus far pertained to the manufacture of iron. John Bourne in his treatise on the steam engine (1861) was the first to advocate pulverized coal for boiler firing; he expressed the idea that the only feasible way to obtain maximum efficiencies in boiler firing was to feed the fuel and the air into the furnace premixed; to accomplish this, of course, the solid fuel had to be reduced to dust.

In the year 1868 T. B. Crampton made some complete investigations and carried out a long series of experiments in the use of pulverized coal for firing puddling furnaces and boilers. The boiler tests were conducted in a marine boiler having 1500 sq. ft. of heating surface, from which the grates were removed and the firebox lined with firebrick. The mixture of coal and air was injected into the furnace and in a 24-hr. test his records show that the temperatures of the exit gases varied only from 380 to 400 deg. F., the evaporation being 10 to 11 lb. of water per pound of fuel consumed with a smokeless stack emission, a phenomenon hitherto unknown. This boiler performance was remarkable in the light of the knowledge then available; it satisfied all requirements save one: the operation could not be carried on continuously and thus failed to be adopted commercially. The reason for failure was lack of knowledge of proper furnace design and lack of appreciation of the relations that exist between furnace volume and rate of combustion.

About this same time—1867 and 1868—Chief Engineer B. F. Isherwood of the U. S. Navy carried out some evaporative tests at South Boston on behalf of the U. S. Government. They used the apparatus patented by Whelpley and Stoerr, of Boston, Mass. This scheme comprehended the simple operation of feeding powdered coal so as to cause it to come into contact with a supply of air for combustion. It was used merely as supplementary fuel sprayed over a bed of fuel on a grate, the idea being that the fuel entering with the column of air would meet the flames of the fire immediately upon injection into the furnace, and be quickly and completely consumed. These tests were made both with anthracite and semi-bituminous coals, the results indicating that, due to the cost of pulverization, much better results were obtained when using grates alone.

For the greater part of the next two decades the subject of pulverized-coal firing was virtually dormant. About the year 1895 this subject again became quite active, following the successful demonstration of Messrs. Hurry and Seaman at the Atlas Cement Co.'s works that pulverized fuel could be used as effectively and more economically than fuel oil for firing cement kilns.

THE BETTINGTON BOILER

In August, 1906, James H. Bettington visited the United States as a consulting engineer for one of the large South African cement plants, purchasing at that time from the principal manufacturer of cement-mill pulverized-fuel equipment a plant for the Alpha Portland Cement Co. Later he decided to extend the method to boiler furnace firing and in conjunction with Frazer & Chalmers, Ltd., of England, developed a vertically fired, bottom-burner, water-cooled boiler furnace utilizing air preheaters and unit pulverizers. Bettington succeeded in burning South African and Canadian coals containing 20 to 23 per cent of ash on tests at efficiencies ranging from 75 to 80 per cent.

In the United States prior to the year 1909 pulverized coal for boiler firing was given little consideration as a commercial fuel, by industrialists outside the cement industry. The early success and apparent simplicity of burning powdered coal in cement kilns can be attributed to the knowledge cement manufacturers had of the necessity of fine grinding and their understanding of how to produce finely ground material. This was gained by years of experience in pulverizing rock and clinker for cement manufacture. Furthermore, the rotary cement kilns constituted large combustion chambers and the ash of the

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[1]Consulting staff, Fuller-Lehigh Co.

coal was absorbed by the clinker without deleterious effect. Subsequent experience has taught that not only must the coal be properly prepared, but the boiler furnace must be correctly proportioned to accommodate sufficient fuel to meet all steam demands. Also the form of burner used, the method of admitting fuel and air, velocity and pressure, turbulence of flow, transportation of fuel, furnace regulation, and control are problems which demand close study and experiment.

First Definite Efforts in U. S. to Apply Pulverized Coal Firing to Boilers

It was not until about the year 1909 that any definite and substantial attempts were made in the United States to solve the various problems which had beset and defeated all previous attempts to fire boilers with pulverized coal. About this time the principal manufacturer of pulverized-fuel equipment for the cement industry conceived the idea of further developing the art for boiler firing. An installation was made on a 72-in. by 18-ft. horizontal tubular boiler at the plant of the Lehigh Car Wheel & Axle Works. This, although an experimental installation, was operated from 5 to 16 hr. per day for a period of three weeks on pulverized anthracite coal. These experiments were so encouraging that in 1911 an installation was made at the Allentown Portland Cement Co.'s plant on a 400-hp. Rust boiler. Considerable trouble was experienced due to falling out of bricks and collapsing of the arch. At first it was supposed that brick of inferior quality was to blame, but it was later discovered that a destructive condition had been created in the furnace; more coal was injected into the furnace than the available space could accommodate, resulting in high gas velocities and an erosive action which originally and erroneously had been attributed to high temperature.

This was probably the first installation in the United States in which water-cooled circulation was used to absorb heat from the refractories. Water pipes were put in the brickwork of the arch and the circulating water passed through them direct to the heater, whence it was pumped into the boiler, thus recovering the heat given up by the boiler setting. This boiler was kept in operation some time without serious trouble.

More than 20 yr. ago the Manhattan Elevated Railroad experimented with pulverized coal as a fuel on one of its locomotives. The equipment consisted of a combined pulverizer, blower and steam turbine situated on a locomotive. It is believed that this experiment proved a failure on account of the lack of fineness in grinding the coal and defective methods of burning. In 1914 the New York Central Railroad conducted tests on a locomotive of the ten-wheel type, having a tractive power of 31,000 lb. This locomotive was successfully operated for months and ran daily between Utica and Albany, but the tests were not carried far enough by the railroad company to insure complete success.

In August, 1916, the Missouri, Kansas, and Texas Railway Co., after negotiations extending over 3 yr., equipped eight O'Brien water-tube boilers at their shops at Parsons, Kan. As a result of rising costs for fuel oil with which the boilers were originally fired, the officers of the railway company investigated other methods for generating steam. Within an economical freight-rate range of the plant were coal and lignite mines in Kansas, Oklahoma, and Texas.

It was in this plant that it was first proved that the coal must be properly dried, and finely and uniformly ground for best results; that a definite relation exists between the size of combustion chamber and the amount of coal that can be burned in a given time; the boilers must be correctly baffled and that a scheme of baffling which is satisfactory for gas and oil firing is not necessarily the best system for pulverized-coal firing; that this method of burning fuel is not necessarily more destructive to refractories than older methods; that the disposal of ash is not a bar to its use, provided the methods are adapted to the characteristics of the coal; and that better boiler control can be obtained and better overall operating records result when powdered coal is used.

Experiments on the Franklin Boiler in 1915

About this same time experiments were conducted on a 300-hp. Franklin boiler at the Schenectady Works of the American Locomotive Co. The first design of this furnace proved unsatisfactory, largely through lack of proper combustion space and the design was changed. The coal is introduced into the main supply of air, which was under a pressure of about 0.3 in. of water, by means of a jet of compressed air under pressure of about 20 lb. per sq. in.

The pioneer large central-station installation was made in 1920 when the Milwaukee Electric Railway & Light Co. installed eight new 1306-hp. Edge Moor boilers in the Lakeside station to use powdered coal exclusively. This plant was decided upon after the company had experimented for a number of years with powdered coal in its Oneida Street plant, by which they were convinced that this method was the most satisfactory, efficient, and economical. The new plant was designed and built under the direction of John Anderson, chief engineer, in collaboration with the engineers of the two largest pulverized-fuel-equipment manufacturers, one of whom furnished the driers, pulverizers, and conveying equipment, while the other furnished the feeders and burners which deliver the fuel into the furnaces.

Under operation they have developed 200 to 300 per cent of nominal rating continuously. Here all of the best experience of the past was applied and the irrelevant and erroneous eliminated to the extent that when tests were made in 1921 by the U. S. Bureau of Mines in cooperation with the designing and operating engineers, the claims for the new method of firing fuel proved more than justified.

Pulverized-coal firing may be considered to have passed the experimental stage for industrial use in 1916 and for central-station use in 1920. Not only is this system of firing entirely relied upon in some large and important plants, but it has been adopted in connection with some of the largest steam-boiler units yet installed. The principle of pulverized-coal firing permits of large furnace capacities and the tendency is now toward much larger boiler units and a very much higher operating rating than has hitherto been thought possible.

Large Boiler Installations Now Using Pulverized Coal

Impressed by the possibilities of pulverized-coal firing, many of the large boiler installations made during the past 4 yr. have adopted this method, the present year witnessing some 1,060,000 to 1,100,000 sq. ft. of new installations served. There are now at least 300 installations in

this country in which pulverized coal is used and nearly 20,000,000 T. of coal per year are being pulverized and burned.

The foregoing necessarily brief historical review shows that the main principle of introducing the fuel and air together was conceived nearly a century ago, but was not put into successful operation till comparatively recently. It will be granted by all that it is at least a valuable additional method that will bring great benefits to mankind, and will help in conserving our fuel supply. In view of this it is of interest to us as the present-day representatives of the engineers of the past 100 yr. to ask ourselves whether the long delay in beginning to reap benefits from the idea indicates failure in knowledge, ability or energy on the part of the profession. The requisites of the necessary details now appear obvious, and are based on elementary principles consequent on the main principle or on each other.

Use of Electrically Driven Auxiliaries Increases

Details of Motors and Controls, as Well as Source of Auxiliary Power, Shown by Recent Investigations of Modern Central Stations

IN ORDER to learn the trend of present practice in driving auxiliaries in central stations having units of over 20,000 kw. capacity, a questionnaire was sent out through the Heat Balance Sub-committee of the Prime Movers Committee of N. E. L. A. Answers were received

FIG. 1. ENCLOSED SQUIRREL CAGE MOTOR WITH PIPE VENTILATION

giving the details of 33 stations, but complete answers were not given in every case. The following discussion brings out the principal points of interest in the practice of these stations, and is taken from the complete report recently issued by the N. E. L. A.

Allowable Time of Interruption of Auxiliaries

Interruption of the boiler feed water for more than one minute, on the average, is not permitted in modern boiler room practice, unless the load is dropped, and even that much could not be allowed if boilers are operating at maximum capacity. Pumps must be arranged, therefore, to give constant feed-water supply regardless of disturbances in their power systems.

Some stations use all steam-driven pumps, others use motor-driven pumps with steam pumps held in reserve. Variable speed motors are usually employed, the only alternative being to throttle the feed line to take care of changes in load.

In most cases, circulating pumps must operate continuously, as the load on the generating unit cannot be maintained if the circulating water supply fails. Usually the longest allowable period of interruption is that required for the automatic switching apparatus to change from one source of power to another or to start a standby unit. Such switching devices should function in 15 sec. or less.

Some plants have no duplicate circulating pumps. A more common arrangement is that of two motor-driven pumps, each large enough to operate the unit at full capacity. Sometimes a few of the pumps are steam driven.

When electric drive is used for circulating pumps, variable speed motors with a speed range of about 33 per cent are used in more than half of the modern stations.

Average conditions will permit condensate pumps to be shut down as long as 3 min. with full load on the turbine, although some operators do not wish to risk a shutdown longer than the time required for automatic electric switches to throw in standby pumps. Most plants use duplicate pumps of full capacity, usually driven by constant speed motors, though in some cases one of the two pumps is steam driven to aid in starting the plant from a cold state, especially if it is an isolated plant.

Service of air pumps may be stopped for six or seven minutes and, if the condenser is tight, often for as much as 30 min., before the vacuum is seriously affected. Many plants, therefore, have no duplicate air pumps. A few use the duplicate installation, one of the pumps sometimes being steam driven; in other cases a steam operated air ejector is employed. As a rule, constant speed motors are used for this service.

On the average, 1½ min. is the time that forced draft fan service can be stopped, and one min. for induced draft fans, without causing trouble. If the generator output is interrupted, some engineers believe it is desirable to arrange fan drives so that the fans will shut down. Since it is often hard to install duplicate forced draft fans, they sometimes discharge into a header supplying all furnaces. Variable speed motors are generally provided, with an average speed range of 50 per cent.

Interruption of Coal Handling Machinery

Stokers should operate continuously if full load is to be carried without interruption. Stoker motors must not be shut down longer than 3½ minutes, on the average. As with the fans, it may be an advantage to have stoker motors stop in case of generator shut down. It is usually not desirable to duplicate stoker motors unless it is desired to use line shafting and clutches. Variable speed motors are commonly used.

Clinker grinders usually do not require continuous operation; in fact, many plants do not use them. They are driven by variable speed motors with a speed range of 75 per cent. Service pumps, usually driven by constant speed motors controlled by tank floats, are operated according to local conditions. The same is usually true of air compressors. Coal handling machinery is usually in-

stalled in such a way that a 24 or 48-hr. supply of coal can be handled in 8 hr.

Supply of pulverized fuel cannot be interrupted for more than a minute if a load is to be carried. The same is true of pulverized fuel blowers. Variable speed motors, with a wide range in small steps, are commonly used for pulverized fuel feeders and constant speed motors for the blowers.

Types of Motors and Control Available

Most central station operators appreciate the importance of proper use of motors for driving auxiliaries. Reliability is the first consideration, since continuity of service and safety of equipment is almost as dependent on certain auxiliaries as it is on satisfactory operation of the main units. Equipment for driving auxiliaries should be selected, therefore, with full knowledge of the special requirements to be met and the limiting features of the drive selected.

This means that the simplest type of motor should be used consistent with these conditions. Also, if the motors are exposed to coal and ash dust, moisture, oil or water drips, they should have special insulation and suitable closed frames and end shields.

Usually it is not found economical to build totally enclosed motors in sizes above 25—30 hp., on account of the extreme size necessary to radiate the heat losses. Above these sizes, enclosed ventilated construction is preferable. A typical example of this construction is shown in Fig. 1.

When motors are located in favorable places, they may be of standard open construction. But when installed in rooms likely to have explosive mixtures of oil vapor, gas or powdered coal, squirrel cage motors should be used, or if the drive requires slip-ring motors, these can be obtained with explosion-proof enclosed collectors, as shown in Fig. 2. Proper protection of bearings, by a dust proof seal, is often advisable to prevent coal and ash dust from getting into the bearings.

Motors for central station use should be designed liberally as regards heating, as the surrounding temperatures are often high. It is generally felt that a temperature rating of 40 deg. C. rise at rated load is satisfactory for central stations.

If a.c. motors are used in large central stations, it seems uneconomical to use voltages below 2200 for the principal auxiliaries, especially those above 50 hp., because the currents to be handled are excessive with lower voltages. For sizes under 50 hp., 550, 440 or 220 v. may be used. With d.c. motors, 230 or 550 v. may be used, since standard motors are built for these voltages.

From actual operating conditions it has been found that low voltage starting of squirrel cage motors is unnecessary and undesirable. In the newer stations, full voltage starting has been adopted in many cases. Since central station auxiliaries are started infrequently, it is doubtful if full voltage starting has an appreciable effect on the life of motors properly designed for it.

To meet the requirements of full-voltage starting, the double squirrel cage motor starts smoother and draws less starting current than the single squirrel cage type. Slip-ring motors are ordinarily started on full voltage, provided that the control puts proper secondary resistance in the circuit. Commutator type a.c. motors are self-starting at full voltage, at any brush position that gives enough torque.

Since power for auxiliaries is usually taken either partly or wholly from the main bus, the currents that flow in case of short circuit are large, hence the control equipment must have large rupturing capacity. Industrial motor control apparatus is not suitable for this service, since in general it is not designed to rupture more than the locked rotor current of the motor. In existing stations employing standard industrial compensators, which, for various reasons, cannot be replaced, it is recommended that they be placed behind steel panels to protect the operator.

Magnetic contactors are used in many cases but, since the surface of these contactors are not cleaned by frequent use as often as in industrial plants, it is advisable to use contactors more conservatively rated. Furthermore, such contactors are not designed to take the place of circuit breakers, therefore their mechanical strength and thermal capacity are limited.

Relay protection for auxiliary motors is as follows: under-voltage protection, overload protection, protection against internal faults and thermal protection.

Under-voltage protection is usually omitted on essential auxiliaries, in order to keep them on the line under momentary drop of voltage. Overload protection is sometimes

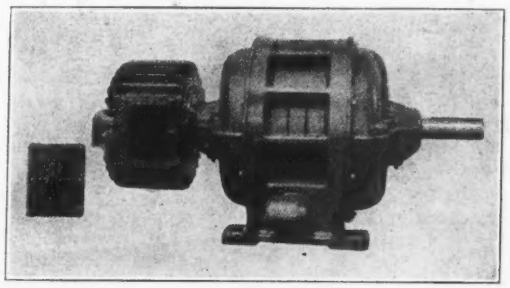


FIG. 2. SLIP RING MOTOR HAS OUTSIDE, EXPLOSION-PROOF, ENCLOSED COLLECTORS

omitted when differential protection is used. When overload protection is used, the loads are definitely fixed by the apparatus driven and overload relays are set high to protect the motor if it stalls. Differential relays are used for protection against internal faults. A negative phase sequence relay is available for protection against phase unbalance, open phase, and reversal of phase. Thermal relays may be had with temperature characteristics similar to the motors they protect.

Application of Motors to Various Auxiliaries

High speed pumps are necessary with high pressure boilers; motors up to 400 or 500 hp., with speeds up to 1800 and even 3600 r.p.m., are being built for this work. Slip-ring motors with secondary control are satisfactory here, and may be controlled by pressure regulators and motor operated drum controllers. If constant speed motors are required, synchronous or squirrel cage motors can be used.

Where constant speed is needed for circulating, air and condensate pumps, squirrel cage or synchronous motors can be used. If it is desired to reduce the quantity of circulating water during the winter months, two-speed squirrel cage or wound rotor motors can be installed. With the latter, speed variations are easily made.

Since boiler room fans usually require a speed range of about 50 per cent in 12 to 18 steps, a wound rotor motor gives satisfaction. If boilers are to be worked over a considerable range, as much as 70 per cent variation in fan

speed may be needed. In such cases, two motors may be used, the larger one being connected to the fan shaft by a magnetic clutch. The smaller motor is of the proper size to carry the usual load and the large motor handles maximum loads. The latter is shut down when not in use, but, when it is driving the fan, the small motor runs idle on the fan shaft and must be designed to withstand the high speed. Automatic control can be applied to connect these motors properly to the circuits.

Commutator type a.c. motors are well adapted to fan drive, although higher in first cost than slip-ring motors. The brush shifting motor provides an infinite number of variations, while the slip ring motor control is limited usually to 18 points.

For stoker drives, the essential requirements are constant torque and wide speed range, often 75 per cent. Mechanical transmission is sometimes used to simplify the electrical control, even in connection with constant speed, two-speed, or wound rotor induction motors. Direct-current motors with field control give good results, and d.c.

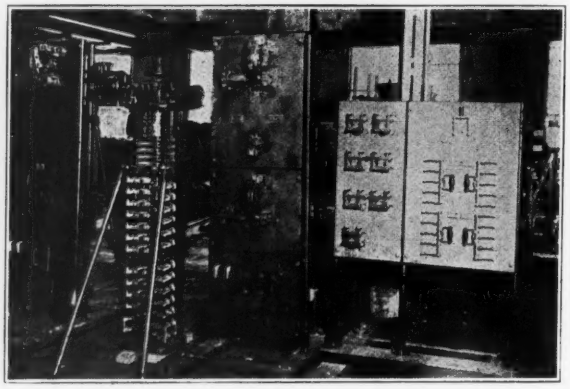


FIG. 3. PRIMARY PANEL AND SECONDARY DRUM FOR SPEED CONTROL OF DRAFT FANS DRIVEN BY TWO WOUND-ROTOR INDUCTION MOTORS

shunt motors, separately excited with either armature or field voltage adjustment, are sometimes used. If it is desired to use only a.c. motors, wound rotor pole changing motors will give speed ranges from 300 to 1200 r.p.m. Four-speed squirrel cage motors can also be used and the polyphase commutator motor of shunt characteristics is well adapted. Wound rotor motors are not well suited to stoker drives, as they have series characteristics with resistance in the secondary, and are liable to vary in speed and have low stalling torque.

Constant speed auxiliaries such as service pumps and air compressors, can be well driven by squirrel cage motors, although synchronous motors have given good results with air compressors.

Squirrel cage motors are often used for coal handling equipment, which requires constant speed, although wound rotor motors will give high starting torque. Voltages for these motors are usually 220 or 440. Suitable push-button-operated compensators are commonly used with larger motors and contactor type full-voltage starting switches with the smaller. Interlocking connections are often used, so that the crusher cannot be started until conveyor and elevator are running. If skip hoists are used, two-winding, two-speed squirrel cage motors with hoist controls are employed.

With pulverized fuel equipment, squirrel cage motors are satisfactory for the blowers. For the fuel feeders, d.c. motors are most satisfactory. If a.c. drive is necessary, wound rotor pole-changing motors with secondary resistance control are good. A safer method, however, is to use a constant speed squirrel cage motor with mechanical variable speed transmission. For pulverized fuel equipment, the safest arrangement is to use totally enclosed, pipe-vented motors with either forced or self-ventilation. This prevents danger of explosion even in case of internal short circuits in the motor.

Importance of Auxiliary Power Supply

The design of the electrical supply for steam central station auxiliaries is dependent on a number of factors. The most important one to consider is the purpose for which the station is designed, that is, whether it is to supply a base load, a system load, or to be used for standby service only. The expenditure warranted to obtain a reliable auxiliary supply for the base load or system load station may not be justified for the standby station.

Another factor entering into the problem is, whether the station will be isolated from other stations supplying its own individual area, or whether it is to be linked with other stations by tie lines. In the former case, it would be necessary to provide for starting the first time or after a complete shutdown; in the latter, the tie line connection might be considered as an adequate source of power for these purposes. However, any station of a number supplying a large system may become virtually isolated because of tie line failures or shutdown of other stations, and the possibilities of occurrences of this kind must be taken into consideration. Many engineers, therefore, feel that a station should be designed to start independently of any other station.

The heat balance scheme to be used has a bearing on the design of the electrical supply system, as the use of many steam driven auxiliaries, particularly the more essential ones, for supplying exhaust steam for heating the feed water, lessens the necessity for an uninterrupted electrical supply. Where stage bleeding is used there is no necessity for steam-driven auxiliaries for this purpose. Furthermore, the adoption of higher steam pressures may discourage the use of many steam-driven auxiliaries because of the expense involved. Under these circumstances, practically all of the auxiliaries will be electrically driven, thereby necessitating a power supply of the maximum reliability.

In laying out any electric power supply for auxiliaries the following considerations, listed in the order of their importance should be kept in mind: (a) reliability, (b) simplicity, (c) cost, which includes first cost, maintenance, operating costs, and operating losses.

It is generally conceded that reliability is the most important factor to consider, as the reliability of the entire station and even the system may be dependent upon the station auxiliary supply, particularly that to the more essential auxiliaries, and while the constant effort of all operating companies is to reduce costs, it is not considered good practice to jeopardize continuity of service for any slight saving. A problem closely related to the reliability and cost of the auxiliary system is that of spare capacity and duplication of units for the various sources of power. Obviously it is desirable to have sufficient spare equipment to carry the auxiliary load after apparatus failures without

overloading remaining equipment. In the final analysis, the entire question is one of engineering judgment, where the degree of reliability is balanced against the initial cost, but in good central station practice, the former is favored to an extent which would not be considered in many industrial plants. On the other hand, where the savings are large and the decrease of reliability very slight, good engineering practice would not sanction an utter disregard of these savings, although reliability remains the paramount consideration.

Closely related to reliability is simplicity, as the layout should be of such a nature that the operator will not be confused at times of stress.

The design of the auxiliary supply system should be such that maintenance work may be completed in a minimum time, as it is desirable to have outage of equipment short; this may incidentally reduce maintenance costs.

Power House Lighting Merits Attention

In view of the great importance of lighting, it is generally considered advisable to have certain selected lamps in important locations supplied by a storage battery upon the failure of the station supply system, thus insuring continuity of this lighting. In some installations these selected lamps are normally carried by the regular station supply system and arranged to be thrown over automatically to the battery. In others they are supplied by a motor generator set operating in parallel with the battery. The latter practice is considered preferable, since it eliminates any automatic throwover device. This matter is considered of such vital importance that some engineers believe a large storage battery warranted for this purpose alone, even though there might be no other necessity for it, such as for excitation or emergency power supply. The necessity of continuous lighting, not only from a personal safety standpoint but also to facilitate the return to regular operation, is apparent. Great care should be exercised not only to insure that this supply is unfailing, but also to select the best location for the lamps.

In general, there are six sources of electric power for the supply of auxiliaries in addition to a number of special methods to be touched upon later. These are as follows:

Main bus bars through transformers,

House turbines,

Shaft generators,

Transformers connected to generator leads,

Supply from another station by means of a feeder not directly connected to the main bus bars,

Direct current with storage battery reserve.

It is found that the power supply is seldom confined to any one of the above methods but more generally to a combination, two or more of them sometimes being supplemented by separate steam driven units or duplex drive.

Connections for supplying auxiliary power from the main bus through transformers are shown in Fig. 4-A. This system is simple and rugged; first cost, maintenance and operating costs are low. It has the disadvantage that it is subject to interruption by disturbances in the system. The loss of such units as circulating and boiler-feed pumps would result in a shut-down of the whole plant. The plan should not be employed, therefore, for supplying these auxiliaries unless they are reinforced by duplex sets, or a "spinning" house turbine.

When house turbines are used, the auxiliary supply is not affected by system disturbances, but power cannot be generated as economically as in the main turbines, and there are increased mechanical and electrical complications. The house turbine can be used for heat balance, its exhaust heating the feed water; when thus used, essential and non-essential auxiliaries can be connected to give the proper load, as shown in Fig. 4-B. The two busses may be tied together either by an oil circuit breaker, an induction motor, a motor-generator set or a saturated core reactor as at W, X, Y and Z, Fig. 4-B.

Another variation of the use of the house turbine is to operate it "spinning" or floating on the line at no load, but with the turbine governor set to pick up the load if the regular supply is interrupted. When this is done, the generator, operating as a motor, is overexcited. An incidental advantage is that it draws a leading kv.a. and improves the power factor of the auxiliary system. The turbine may require a small amount of steam to keep the blades cool, or it may run in the vacuum of the main condenser. Such a "spinning" house turbine may also be used as a standby set.

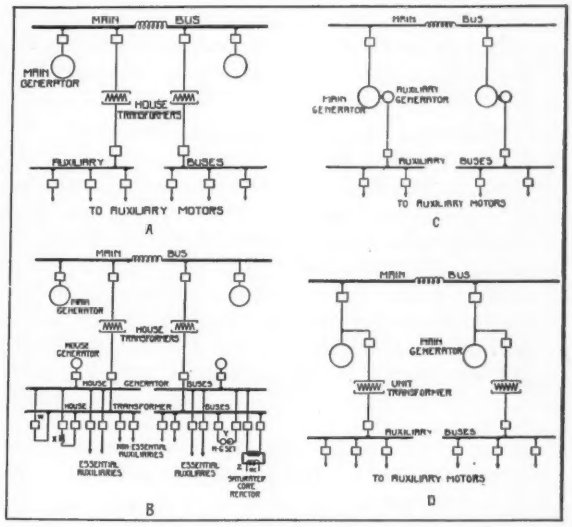


FIG. 4. A—AUXILIARIES SUPPLIED FROM MAIN BUS THROUGH TRANSFORMERS. B—AUXILIARIES SUPPLIED FROM TWO SOURCES IN PARALLEL. C—SHAFT GENERATORS MAY SUPPLY AUXILIARIES. D—SUPPLY FROM TRANSFORMERS CONNECTED TO MAIN GENERATOR LEADS

Supply from house turbines is reliable and well adapted for essential auxiliaries. It is, however, subject to a heavy voltage drop when large motors are started at full voltage and should be equipped with voltage regulators.

In the case of an auxiliary generator mounted on the shaft of the main unit, as shown at Fig. 4-C, the auxiliary power is not affected by system disturbances and the reliability is high. There are, of course, increased mechanical complications of the main unit, heavy voltage drop occurs when starting large motors and if the throttle of the main unit is tripped, auxiliary supply is lost.

This arrangement gives auxiliary power at approximately the same cost as that of the main unit. It is customary to install an exciter on the end of the main shaft. As with the house turbo-generator, voltage regulators should be used. Also, the system should be reinforced by an emergency supply from the main bus.

In taking auxiliary power through transformers from the generator leads, as shown in Fig. 4-D, a transformer bank is connected at a point between generator terminals and the main oil circuit breaker, so that the supply to the auxiliaries will continue if this circuit breaker opens. The costs of this system are low; it is simple, rugged and reliable, and starting of motors at full voltage does not affect it. However, system disturbances can be reflected into it, and if the main unit stops, the supply is cut off. It would, of course, be reinforced by transformers connected to the main bus.

Where a nearby plant of the same frequency is available or where machines of a different frequently are installed, these sources of power from an emergency supply to the regular supply, the latter through frequency changers. This, however, should not be considered as the regular supply, as trouble on one station or frequency would interrupt the other by shutting down its auxiliaries.

While general practice is away from the extensive use of direct-current motors for auxiliaries, although two or three of the larger companies believe strongly in this supply, where they are used, an extremely reliable reserve can be provided in the shape of an ample storage battery. This will enable the auxiliaries to continue in operation in the event of a failure of the regular supply from the main bus.

General Practice in Modern Stations

Steam-driven auxiliaries and duplex sets are used generally in conjunction with the above schemes. In practically every station some boiler feed pumps are steam driven and also, for obvious reasons, one of the fire pumps. Where stage bleeding is used, the trend seems to be to keep the number of such units down to a minimum.

To summarize the sources of auxiliary power used by the 33 companies, a tabulation was prepared, showing in detail the practice of the various stations regarding allowable shut-down time, duplication of motors and duplication of units.

Of these 33 stations, 19 take their entire auxiliary power supply from the bus through transformers. The remainder take part of the supply from the main bus, with additional sources as indicated:

Generator leads through transformer	2 stations
House turbines, loaded	6 stations
House turbines, floating	5 stations
House turbines, emergency	3 stations
Shaft generators	6 stations
Outside distribution system	1 station
Storage battery reserve	5 stations

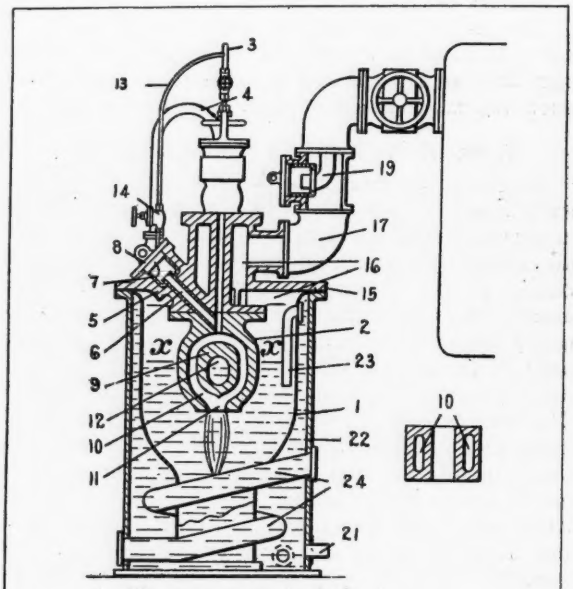
Included in the report are detailed diagrams of the auxiliary systems at each of the stations mentioned. There is also an exhaustive bibliography. This is followed by detailed consideration of the application of motor drives to circulating pumps, fans and stokers, with reports of tests.

The Brazilian Portland Cement Co. is building the first cement mill in that country. This plant, which is located about 12 mi. from Sao Paulo, will have a capacity of 1000 barrels per day and will be completely electrified. General Electric equipment has been ordered for the plant, including one 200-hp. and two 500-hp. synchronous motors; three 500-kv.a., 44,000/2300-v. transformers; switchboard and substation switching equipment; two 50-kw. motor generators and 24 motors ranging in size from 10 to 100 hp.

Internal Combustion Boiler Burns Flame Under Water

By C. H. S. Tupholme

BURNING AN OPEN flame under water may sound like magic but judging from reports made available in London at a joint meeting of the Institution of Chemical Engineers and the Chemical Engineering Group, it is a comparatively simple matter provided it is done in the proper way. In fact, it forms the basis of the Brunler Internal combustion boiler which was the subject of much discussion at the meeting.



1 The steam generator body
2 The burner
3 The oil pipe
4 The air pipe
5 The cover of the steam generator
6 The ignition lamp tube
7 The fire clay cap of the ignition lamp
8 The cover of the ignition lamp
9 The bridge of the burner
10 The burner passage
11 The burner outlet
12 The water passage through the burner
13 The oil pipe to the ignition lamp
14 The air pipe to the ignition lamp
15 The cover of the generator

FIG. 1. SECTION OF THE STEAM GENERATOR

The details of this boiler were presented by Oscar Brunler, son of the man who first investigated the possibilities of burning an open flame in water. Brunler, Sr., set out to solve the problem of converting more heat into energy, and came to the conclusion that the principle of bringing the flame of the fuel into the closest possible contact with the water in the boiler had about reached its most efficient state, and that if any improvement was to be effected it could be only through burning the flame right in the water. He found that this was feasible notwithstanding the ridicule poured on his project by the European press.

Brunler found that every kind of liquid fuel would burn in the liquid to be heated as long as the amount of

air or oxygen was large enough to ensure complete combustion. This idea is fully demonstrated in the working of the internal combustion boiler, the principle of which is to maintain a flame burning in the liquid in order to evaporate the latter. During the years of experimenting, liquid hydrocarbons of a specific gravity between 0.8 and 1.2 have been used. Tar oil from Belgium, coal tar from Germany, astatki from Baku, waste oil from America, and different kinds of oil from every part of the world have been tried, in all more than 60 varieties, and all could be burnt without difficulty.

Figure 1 shows the steam generator in section. The fuel oil and the air necessary for combustion are supplied

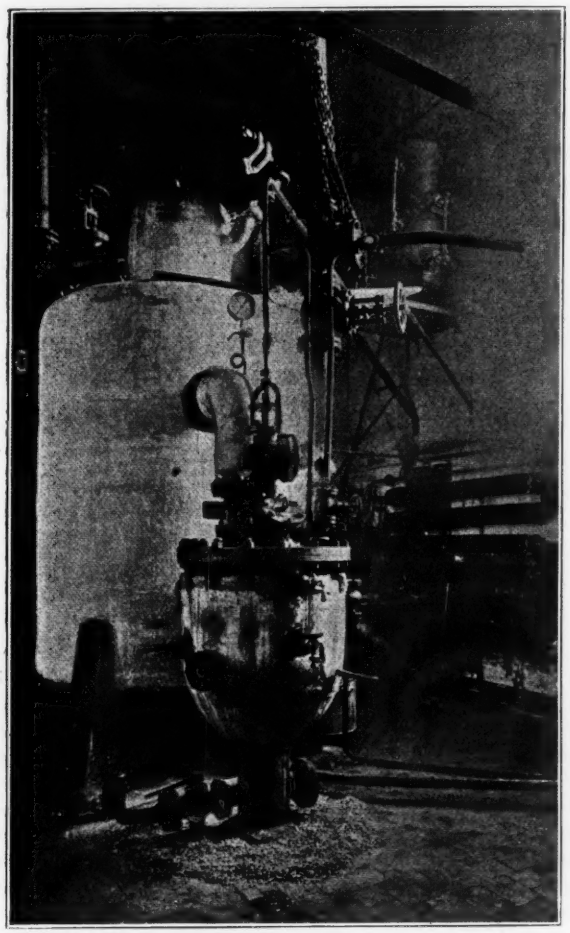


FIG. 2. THE BRUNLER STEAM GENERATING APPARATUS

to the burner under a pressure which barely exceeds the pressure of the steam. Before starting, the connection valve is closed, and the water level in the generator must not be above the lower mouth of the burner. The cover of the ignition lamp is removed after heating the fireclay lining of the ignition lamp, the oil and air igniting on the fireclay lining. Then the cover is pulled down again, and the flame of the ignition lamp makes its way to the burner. After a few minutes the main burner is sufficiently hot, the main regulating valve is opened and the flame burns in the generator.

At this point the connecting valve to the water reservoir is opened and the water in the generator rises up to the middle of the burner. The flame which is burning quietly in the water can be observed through the peepholes in the generator. By means of the superheater the steam generated can be superheated to any required degree, the superheater consisting of a small burner similar to the ignition lamp, and its flame burns in the steam reservoir. The size of the flame, consequently the quantity of steam, is regulated by means of the regulating valve, at the same time the ratio of air and oil being kept constant.

By turning one wheel, the size of the flame can be regulated and the ratio of air and fuel is not interfered with, so that the degree of combustion cannot be affected by mistakes on the part of the attendant. The temperature in the center of the flame is approximately 1800 deg. C., which diminishes to the periphery of the flame, a rapid fall in temperature between the center and the edge of the flame taking place. Since a permanent stream of burning gas has to traverse this fall in temperature, it is evident that the last traces of carbon monoxide are converted into carbonic acid.

It is claimed that this combustion under pressure brings the molecules of the fuel into better contact with the oxygen. [This probably accounts for the short length of flame required for complete combustion.—Editor.] At first the flame gives up the greatest part of its heat to the water due to radiation and because of its contact with the water. Around the flame superheated steam is produced which makes its way together with nitrogen and carbonic acid to the surface of the water and passes into the steam reservoir. The heating surface is the surface of the flame and the surface of the gas molecules that are passing through the water. Within a few minutes after the apparatus is started, the required steam pressure can be obtained and in accordance with Dalton's law, in this boiler in which steam and gas are present, the pressure of the mixture must equal the sum of the pressure of the gas and steam.

The mixture of gases which passes from the steam generator to the steam reservoir contains 60 per cent steam and 40 per cent gases. These are the same gases that are working in gas and oil engines, the only difference being that in these engines the amount of steam is much less.

Flash Light Causes Flash-Over

EXPLOSION of flash-light powder in taking a photograph near a high-voltage circuit recently caused a flash-over in an Indiana power plant, it was reported to the Ft. Wayne Works of the General Electric Co.

This phenomenon was checked by E. A. Wagner, managing engineer of the transformer department. A flash was set off beneath a circuit carrying 13,000 v. Under ordinary conditions 90,000 v. would have been necessary to cause an arc-over across the distance of approximately 9 in. which separated the two wires. The flash powder, located 4 ft. beneath the wires, caused a dead short which threw open the main breakers on the circuit. The dust and hot gases rising between the bare wires were apparently ionized, became conductive and carried the arc.

WHEN STEEL storage tanks are set in place, they should be placed on sand, and crude oil pumped underneath them for the prevention of corrosion of the tank bottoms. In many cases it is good practice to place two or three inches of asphalt on the floor of the tank for the same purpose.

The Steam-Jet Condensing-Type Vacuum Pump*

A Description of the Principles of the Condensing Type Air Ejector Together With a Study of Its Performance

ONE OF THE fundamental requirements in the maintenance of high vacuum in connection with turbine operation is the removal of air and other non-condensable vapors from the condenser. It is, therefore, only natural that much attention should have been given to the development of suitable air pumps for effecting the efficient removal of such gases. Among the devices used for this purpose, the steam jet type of vacuum pump, particularly the condensing type, has reached a high state of development,

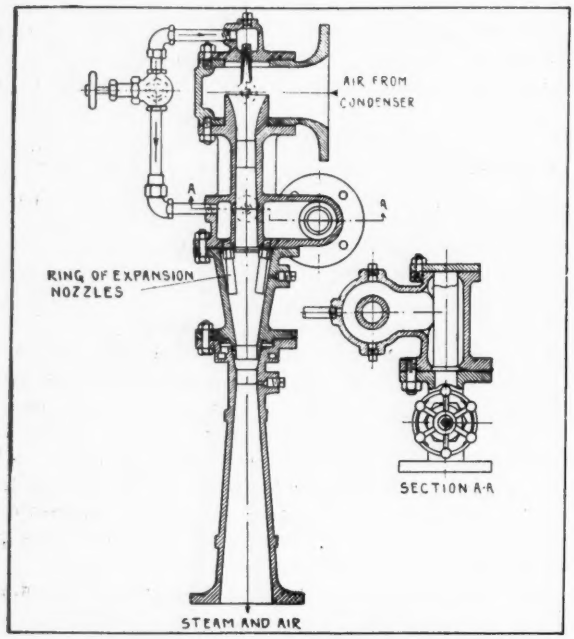


FIG. 1. CROSS SECTION OF A SIMPLE TWO-STAGE TANDEM NON-CONDENSING TYPE AIR EJECTOR

since in addition to its value as an air removal device, it possesses the inherent characteristics of an effective heat reclaiming element.

Air ejectors employ steam under pressure as the working medium, for the purpose of entraining air and other non-condensable vapors, and to compress them from a low to a relatively high pressure. Since high compressions cannot be obtained by a single-stage ejector, it has been necessary to design ejectors with a series of stages. An ejector of this type is shown in Fig. 1, where the second stage is required to handle the air and also the motive steam from the first stage.

Further study led to the design of the condensing type air ejector, such as shown in Fig. 2 the purpose of which is to remove the motive steam used in the first stage, after having completed the initial compression of the air, thus relieving the second stage of this extra duty during completion of the compression cycle, and thereby making possible the use of a lower ratio of compression.

Steam at a predetermined pressure is supplied to the steam nozzles, through which it passes and expands to the desired vacuum, also predetermined. The high velocity of the steam attained during expansion, and not its kinetic energy is utilized to entrain the air by friction from the apparatus being served. The mixture of air and steam is conveyed to the diffuser, in which it is compressed gradually to the pressure obtaining within the intermediate condenser. Steam at the same inlet pressure is supplied to the second-stage nozzle, through which it passes and expands to a vacuum slightly in excess of that prevailing in the intermediate condenser. Since the first-stage steam has previously been condensed in, and subsequently removed from the intermediate condenser, the second-stage ejector has only to remove air, and in addition that quantity of water vapor equivalent to saturation at the temperature and pressure prevailing at the vapor outlet of the intermediate condenser. This mixture of water vapor and air is entrained by the high velocity steam jet into the second-stage diffuser, where it is compressed gradually to atmospheric pressure. The exhaust may or may not be led into an after-condenser; it is essential in either event to maintain the back pressure at a minimum.

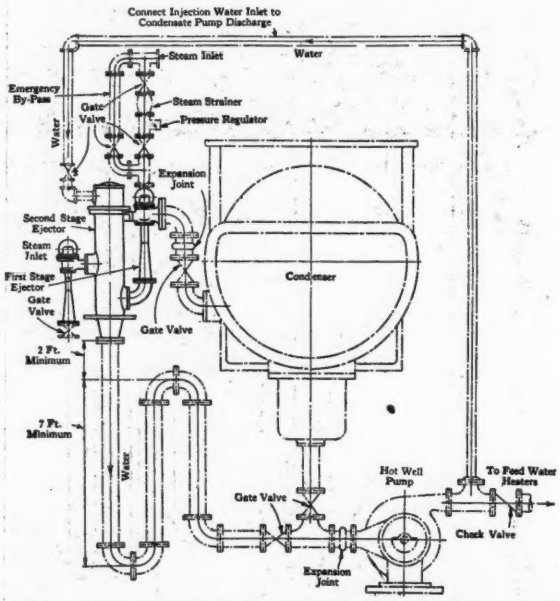


FIG. 2. PIPING DIAGRAM OF SURFACE CONDENSER AND AIR EJECTOR WITH JET-TYPE INTERMEDIATE CONDENSER

Main unit condensate, or extraneous, water is used as a cooling medium in the intermediate condenser for the purpose of condensing the steam by removal and transfer of the latent heat of evaporation, and also for the purpose of further cooling the air and non-condensable vapors before admission to the second stage.

The field of application of the condensing type air ejector is broad and embraces all classes of industrial and power plant apparatus in which the removal of air and other non-condensable vapors is necessary in order to maintain any vacuum up to the highest it is practicable to utilize in the most efficiently designed steam turbine. They are economical and reliable in operation, possess great

*Abstracted from an article by J. H. Smith in the January, 1925, number of the Electric Journal.

flexibility in regard to manner of application, are simple and compact in construction and have a low maintenance cost. The steam consumption of the condensing type of air ejector is materially less than that of the non-condensable type.

Ejector Performance

In studying the performance of a condensing-type air ejector as well as the effect of various factors closely associated with them, the accompanying curves will be of value.

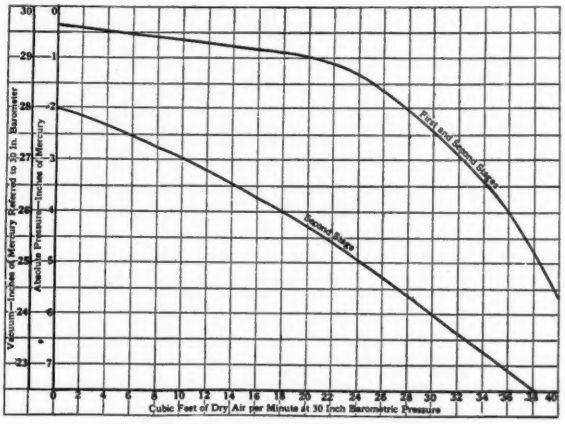

Vacuum—Inches of Mercury Referred to 30 In. Barometer
Absolute Pressure—Inches of Mercury
First and Second Stages
Second Stage
Cubic Feet of Dry Air per Minute at 30 Inch Barometric Pressure

FIG. 3. CHARACTERISTICS OF A TYPICAL CONDENSING-TYPE AIR EJECTOR AT VARIOUS VACUA

The upper curve shows the capacity of the complete ejector with both stages operating; the lower curve shows the capacity of the second stage alone.

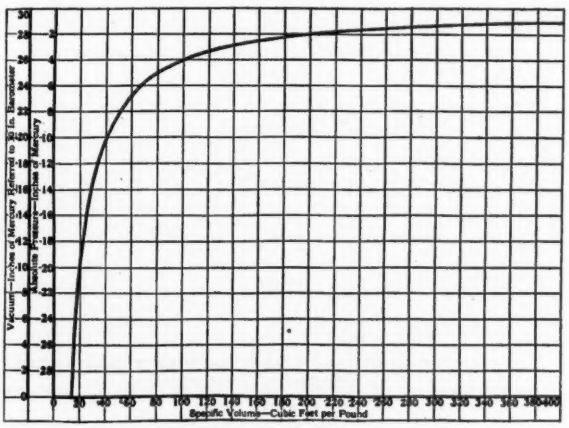

Vacuum—Inches of Mercury Referred to 30 In. Barometer
Absolute Pressure—Inches of Mercury
Specific Volume—Cubic Feet per Pound

FIG. 4. PRESSURE-VOLUME CURVE FOR DRY AIR AT 75 DEG. F.
This curve is plotted from the formula

$$\text{Specific volume} = \frac{0.755 \times \text{absolute pressure}}{\text{Absolute pressure}}$$

Figure 3 is a typical characteristic of a condensing-type air ejector, and shows its capacity in terms of cubic feet of dry air per minute at various vacua, all referred to a 30-in. barometer. The upper curve indicates the capacity of the air ejector when both stages are operating, and is that capacity obtained on dry air test, as the amount of 70 deg. free dry air passed by various sizes of calibrated orifices at various vacua. The lower curve designated second stage indicates the vacuum prevailing at the inlet to the second stage at any capacity indicated on the upper curve, and also the approximate capacity at various vacua when the second stage is operating alone. For example, the capacity of this ejector when exhausting free dry air from a 29-in. vacuum, referred to a 30-in. barometer, and with both stages operating, is 20.2 cu. ft. per min. When operating under this condition the vacuum at the inlet to the second stage is 25.65 in., referred to a 30-in. barometer. In other words, the second stage operating alone will exhaust 20.2 cu. ft. per min. from a 25.65-in. vacuum, referred to a 30-in. barometer.

When serving a condenser, however, the air to be removed therefrom is rarefied and saturated with water vapor, owing to the fact that evaporation obtains at a pressure corresponding to the temperature of water. It is the effectiveness with which the air is cooled under the air baffle in a surface condenser that determines the temperature and pressure of evaporation, and therefore the moisture content of the air.

Dry Air: The physical properties of dry air are based on the following law established by the latest experiments with vapors and gases:

$$\frac{PV}{T} = 0.755 = \text{Constant} \quad \ldots\ldots (1)$$

in which

P = Absolute pressure of dry air, inches of mercury

V = Volume of 1 lb. of dry air, cu. ft.

T = Absolute temperature of dry air, deg. F.

The curve in Fig. 4 is based on the above formula with 75 deg. dry air.

Saturated Air—The weight of saturated water vapor per cubic foot depends only on the temperature and not on the presence of air, for according to Dalton's law each substance will exert the pressure it would if alone occupying the space and the final pressure will be the sum of that of the vapor and that of the air. The various properties of air completely saturated with water vapor may be calculated by means of equation (1) and Dalton's law which can be expressed as:

$$P + P_1 = P_2 \quad \ldots\ldots (2)$$

in which

P = Absolute pressure of dry air in mixture, inches of mercury,

P_1 = Absolute pressure of saturated steam at the temperature of the mixture, inches of mercury.

P_2 = Total pressure, which for atmospheric conditions is 29.92.

Therefore,

$$P = P_2 - P_1 \quad \ldots\ldots (3)$$

P_1 can be taken directly from steam tables, or from the specific volume curve in Fig. 5. The temperature-vacuum curve is also shown in Fig. 5.

Substituting the value for P in equation 3, in equation 1,

$$V_1 = V = \frac{0.755\ T}{P_2 - P_1} \quad \ldots\ldots (4)$$

V = Volume of 1 lb. of dry air (plus vapor to saturate) at pressure P and absolute temperature T.

V_1 = Volume of vapor in 1 lb. of dry air when saturated, cubic feet.

Therefore,

$$W = \frac{1}{V} \quad \ldots\ldots (5)$$

in which,

W = Weight of dry air in 1 cu. ft. of saturated mixture.

The weight W_1 of vapor in one cu. ft. of saturated mixture is the density of saturated vapor at pressure P and temperature T. This may be taken directly from steam tables, or by using the reciprocal of the specific volume in Fig. 5.

The total weight of the mixture is

$$W_2 = W + W_1 \quad \ldots\ldots (6)$$

The weight W_3, or pounds of vapor necessary to saturate a pound of air is

$$W_3 = \frac{W_1}{W} = VW_1 \quad \ldots\ldots (7)$$

In other words, the pounds of vapor necessary to saturate a pound of air at a given temperature and a given total pressure is determined by the ratio,

$$\frac{\text{Density of steam}}{\text{Density of air}}$$

Example: Assume a condenser in which the vacuum is 28 in. and in which a mixture temperature at the air outlet is 75 deg. How many pounds of vapor per pound of air will be removed from the condenser, assuming that the air ejectors are of sufficient capacity?

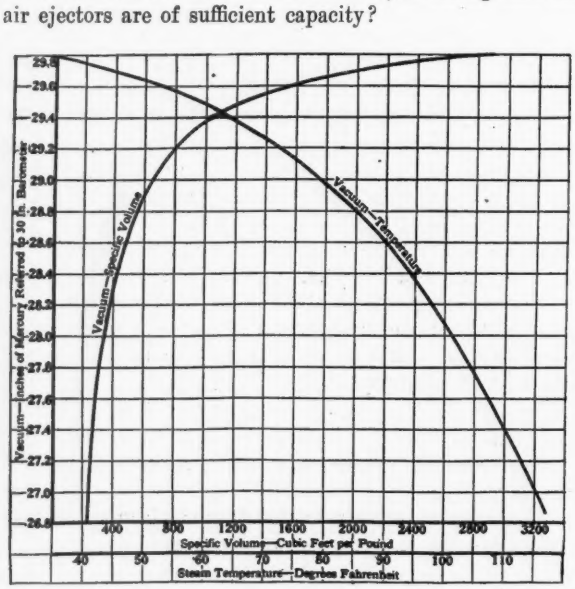


FIG. 5. SPECIFIC VOLUME AND TEMPERATURE OF SATURATED STEAM AT VARIOUS VACUA

Referring to Fig. 5, the vacuum corresponding to 75 deg. is 29.12; that is, the vapor pressure P_1 is 0.88 in. absolute. Since the total pressure P_2 is 2 in. absolute, the air pressure is $P_2 - P_1 = P$, equation (3).

Since this condition deals with saturated air $P_2 - P_1$ is substituted in equation 4, from which

$$V_1 = V = \frac{0.755 \times (75 + 460)}{2.00 - 0.88} = 361 \text{ cu. ft. per lb.}$$

Substituting 361 in equation 5,

$$W = \frac{1}{V} = \frac{1}{361} = 0.002{,}772 \text{ lb. per cu. ft.}$$

The value W_1 or density of steam at 75 deg. and vacuum 29.12 in. is the reciprocal of the specific volume (740 cu. ft.) obtained from Fig. 5; i. e., $\frac{1}{740} = 0.001{,}351$ lb. per cu. ft.

The ratio, $\frac{\text{Density of steam}}{\text{Density of air}} = \frac{0.001{,}351}{0.002{,}772} = 0.48$ is the pounds of vapor per pound of air removed from the condenser.

The above calculations can be eliminated by reference to Fig. 6. Taking the same values as assumed in the above example, the point of intersection between the 2-in. absolute pressure curve and a mixture temperature of 75 deg., and projecting it to the left-hand margin, the value 0.48 lb. vapor per lb. of air is read directly. It follows under the above assumed conditions, that with each pound of air to be removed from the condenser, 0.48 lb. of water vapor must be removed, the total weight of mixture being 1.48 lb. Thus, an air ejector having a capacity of 53 lb. per hr., of free dry air at a vacuum of 28 in., referred to a 30-in. barometer, when required to serve a condenser under the above-assumed conditions, will remove 35.8 lb. of air, and 17.2 lb. of water vapor per hour.

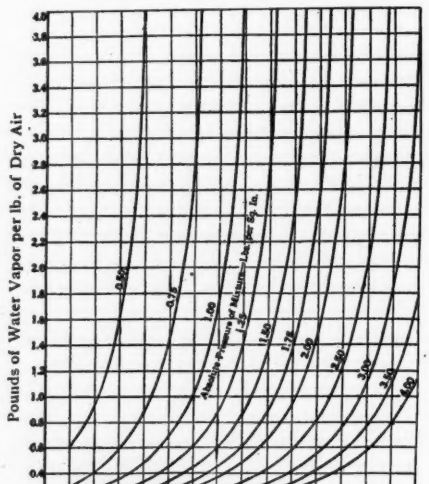


FIG. 6. POUNDS OF WATER VAPOR PER POUND OF DRY AIR REMOVED AT DIFFERENT ABSOLUTE PRESSURES AND TEMPERATURES OF THE MIXTURE

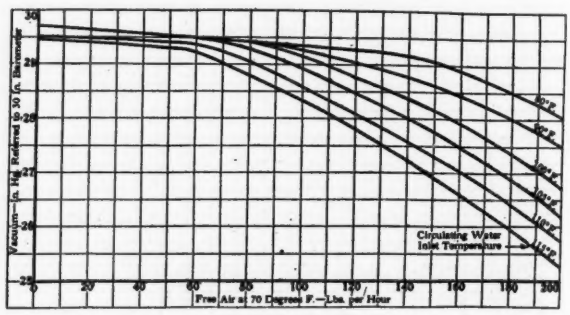


FIG. 7. TYPICAL CURVES SHOWING EFFECT OF COOLING WATER TEMPERATURE ON EJECTOR CAPACITY

It was previously stated that the second-stage ejector bears the same relation to the intermediate condenser that exists between the first-stage ejector and the main condenser. That is, the first-stage ejector withdraws air and

water vapor from the main condenser and compresses the mixture into the intermediate condenser, from which the same air, together with more water vapor, is withdrawn and compressed to a region of atmospheric pressure.

In the preceding study it was demonstrated that the moisture content of the air to be removed from the condenser depends upon the temperature of the mixture and the partial pressures of each constituent, from which the conclusion can be drawn that any reduction of the partial pressure and temperature of the vapor, will correspondingly reduce the vapor content of the mixture. The result is an increase in the air content of a given weight of the mixture to be removed by the air ejector.

The same laws apply in the case of the intermediate condenser, and it is the efficiency of condensation and the temperature to which the vapors are cooled therein, before admission to the second-stage ejector, that actually determines the air handling capacity of the complete ejector unit.

The effect of variable cooling water temperatures is indicated by Fig. 7; thus evidencing the importance of circulating cold raw water through a portion of the intermediate condenser in order to obtain maximum ejector capacity, consistent with water temperature, for all conditions of main-unit load vacuum and condensate temperature. It is obvious, therefore, that the capacity lines indicated in Fig. 7 will vary but seldom, and then only with seasonal changes of the main injection water temperature.

Maybe Your Engine Would Be Improved by This Test

By W. F. Schaphorst

GASOLINE engines are used to a considerable extent these days, therefore it occurs to me that a few words on gasoline engine economy might not be out of place. I have run across an exceedingly simple way in which the efficiency of a gasoline engine can be tested—by simply counting the number of explosions when pulling full load and when pulling no load at all. Subtract the latter from the former and divide by the former and the answer is the mechanical efficiency. Isn't that easy enough?

This method is so simple that some readers might think it is not founded on scientific principles, nevertheless it is scientific. If you will count the number of explosions made per minute by your gasoline engine when it isn't pulling any load at all, it will occur to you that every explosion means "just so much" gasoline wasted. In engines of the hit-and-miss type a certain weight of gasoline is sucked into the cylinder every time and it is that amount multiplied by the number of explosions per minute that is absolutely lost per minute when the engine is running "empty." Thus if your engine explodes 28 times per min. when running "empty," 28 charges of gasoline are lost. If it explodes 120 times when pulling full load, you can assure yourself that during all the time that it is pulling full load there are 28 explosions wasted per minute in running the engine itself because of its internal friction. You cannot get away from the internal friction and as has been proved in many tests in colleges and elsewhere the internal friction is a fairly constant quantity regardless of load. It is therefore plain that when pulling full load there are only (120 — 28 = 92) ninety-two explosions that do useful work. The mechanical efficiency of the engine is therefore bound to be 92 ÷ 120 = 76.7 per cent. Expressed as a formula the rule is:

$$\frac{N_f - N_o}{N_f} = \text{mechanical efficiency}$$

where N_f = number of explosions per min. when pulling full load;

N_o = number of explosions per min. when pulling no load at all.

Should you wish to improve the mechanical efficiency of your engine, the formula shows that the only way in which it can be done is to reduce the number of explosions when pulling no load to the very minimum; 76.7 is not such a "terribly bad" efficiency for a gasoline engine but it is possible to bring it up to almost 90 per cent. It is seldom that we see any gas or gasoline engine of an efficiency higher than 90 per cent because of the greater lubricating troubles than we have with steam engines. A mechanical efficiency of 90 per cent in steam engines is rather common where good care is given the cylinder and bearings.

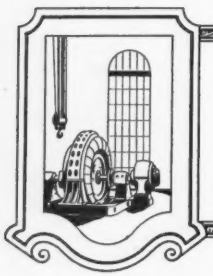
To bring the efficiency of such a gasoline engine up to 90 per cent what would have to be done? What would the number of explosions have to be at zero load? This is easily determined by multiplying 120 by 90 per cent, which gives us 108, or the number of useful explosions that would have to be obtained per minute. Subtracting 108 from 120 we therefore get 12 as the number of explosions per minute at which the engine would have to run when operating at an efficiency of 90 per cent.

At the same time, however, it must be remembered that the power of the engine is being increased. That is a point that is surely worthy of consideration. The number of useful explosions has been increased from 92 to 108, or 16 explosions. 16 is 17.4 per cent of 92 which means that the power of the engine has been raised 17.4 per cent. Thus if the engine was a 50-hp. engine before the test and the improvements were made, the power would be increased by (50 × 0.174 = 8.7) nearly 9 hp. In other words, it would become a 58.7-hp. engine. And the best of all is—not one additional cent's worth of gasoline would be used in developing this power.

It pays to count the explosions every once in a while and get the engine back into efficient running condition. Use the right amount of good lubricant. Use piston rings that are leakproof as possible and yet that consume as little power as possible. In other words, the piston rings must fit the piston and cylinder. Also, always keep the cylinder in good smooth condition, never giving it an opportunity to score. Lastly, keep the bearings properly alined and lubricated at all times. By doing all of these various things, the number of explosions per minute while pulling zero load will be reduced to the absolute minimum and that is exactly what we want as proved in the mathematics above.

Correction Note

Our attention has been directed to an omission in the article "8000 B.Hp. for Standard Oil Co." appearing on page 172 of the February 1, 1925, issue. In the first paragraph on page 176, the sentence reading, "The pipe joints are all Vanstoned and fitted with Goetze corrugated copper gaskets, etc." should read, "The pipe joints are all Vanstoned and fitted with either Metallo or Goetze corrugated gaskets." Mention of the Metallo gaskets was omitted.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Modern Practice in Power Plant Wiring

EXCEPT FOR CERTAIN TYPES OF CONDUCTORS, HEATING RATHER THAN VOLTAGE DROP, IS PRIMARY CONSIDERATION IN POWER HOUSE WIRING. BY ERIK G. SOHLBERG*

POWER PLANT WIRING is a phase of power plant engineering which in spite of its importance has been accorded little attention in the general literature covering power plant design. It seems to have been taken for granted that if generators and a switchboard were provided, the wiring would take care of itself. It is the purpose of this article to set forth conservative practice in power plant wiring which should prove satisfactory and reliable in operation, if applied with reasonable care without being unduly expensive. This may be applied to substations as well as to generating stations but not to distribution systems (either overhead or underground) nor to wiring on apparatus which properly comes under the scope of the particular apparatus which may be under consideration.

Due to the poor condition of ventilation under which power plant wiring is usually installed, heating rather than voltage drop in the conductors becomes the primary consideration except for intermittently operated control cables, which are designed to carry currents greatly in excess of their continuous rating for short periods of time. In such cases heating is generally negligible and the size of conductor is determined by the permissible voltage drop.

Maximum temperature of an insulated conductor must be limited to that which the insulation will withstand without injurious effects. The allowable rise, then, becomes the difference between this temperature and the maximum room or duct temperature. The accompanying tabulations are based on 35 deg. C. maximum for this temperature. Adjustments must be made for higher, and may be made for lower, temperatures.

Maximum temperature of bare conductors must be limited to that which connected apparatus can withstand without affecting their operation by warping them out of alinement by oxidizing contact surfaces or by undue straining from expansion. The connections being good conductors for heat as well as for electric current, tend to maintain the apparatus at their own temperature. It is good practice, therefore, to set an appreciably lower temperature limit for conductors than for apparatus and thus aid heat dissipation from the latter rather than aggravate it by allowing heat to be conducted in the reverse direction; i.e., from conductors of higher to apparatus of lower temperatures.

As in the case of any heated body, the final temperature of a conductor will be reached when energy losses equal heat dissipation by the surrounding medium. The energy losses in power plant wiring are practically all the $I^2 R$ losses. A relatively small loss is also represented by dielectric hysteresis in the insulation, which increases with the temperature and as the square of the voltage. This loss becomes a practical consideration, however, only in high voltage cables, such as are used for underground distribution. For the purpose of this article it needs no further comment. Dissipation of the energy loss depends on:

(a) The thickness of insulation.

(b) Its thermal resistivity.

TABLE I. TYPES AND SIZES OF CONDUCTORS AND THEIR USE IN POWER HOUSE WIRING

Circuit In order of Relative Importance From Viewpoint of Hazard Due to Failure.	Current	Max. Voltage	Open Wiring Protected By Elevation, By Barriers, Compartments or Screens. Bare Conductors				Open Wiring Exposed Insulated Single Conductors Braided. Flame Proof Finished		Conduit Wiring Dry Conditions Insulated Stranded Cables Braided. Weather Proof Finished		Conduit Wiring Wet Conditions. Insulated Stranded Cables Lead Covered	
			Wires	Tubes	Bars	Cable	Solid Wires	Cables	Single Cond.	Multicond.	Single Cond.	Multiconductor
House Service Bus	D.C	2300	#6-4/0	AMY, ATD BICH	4 x 1/4							
House Service Generators & Exciters Mains	D.C.	600	#6-4/0	AMY, ATD BICH	4 x 1/4		#6-4/0 B&S	250000-2000000	#6-2000000		#6-2000000	
Field	D.C.	600							#12-4/0 B&S	#12-#8 B&S	#12-4/0 B&S	#12-#8 B&S
House Service Generators Mains	A.C.	2300	#6-4/0	AMY, ATD BICH	4 x 1/4		#6-4/0 B&S	250000-2000000		#6-750000		#6-750000
Field	D.C.	250					#6-4/0 B&S	250000-2000000	#6-2000000	#6-750000	#6-2000000	#6-750000
House Service Transformers	A.C.	2300	#6-4/0		4 x 1/4		#6-4/0 B&S	250000-2000000	#6-2000000*	#6-750000	#6-2000000**	#6-750000
Station Auxiliaries	D.C.	600							#6-2000000	#6-750000	#6-2000000	#6-750000
Station Auxiliaries	A.C.	2300							#6-2000000*	#6-750000	#6-2000000**	#6-750000
Storage Battery	D.C.	250	#6-4/0		1x1/8-4½	250000-2000000	#6-4/0 B&S	250000-2000000	#6-2000000	#6-750000	#6-2000000	#6-750000
Governor Control	D.C.	250								#12-#8 B&S		#12-#8 B&S
Generator Field	D.C.	250					#6-4/0 B&S	250000-2000000	#6-2000000	#6-750000	#6-2000000	#6-750000
Main Bus & Connections	A.C.	13800	#1/0-4/0	AMY, ATD BICH	4 x 1/4		#6-4/0 B&S	250000-2000000				
Main Generators	A.C.	13800					#6-4/0 B&S	250000-2000000	#6-2000000*	#6-750000	#6-2000000**	#6-750000
Main Transformers Low Tension	A.C.	13800	#6-4/0	AMY, ATD BICH	4 x 1/4		#6-4/0 B&S	250000-2000000	#6-2000000*	#6-500000	#6-2000000**	#6-500000
Main Transformers High Tension	A.C.	220000	#6-4/0	AMY, ATD BICH	4 x 1/4	250000-750000						
High Tension Bus	A.C.	220000	#6-4/0	AMY, ATD BICH	4 x 1/4	250000-750000						
Control	D.C.	250							#12-4/0 B&S	#12-4/0 B&S	#12-4/0 B&S	#12-4/0 B&S
Instrument Wiring	D.C	250							#12-8 B&S	#12-#8 B&S	#12-#8 B&C	#12-#8 B&S
Station Ground Bus			#6-4/0		1x1/8-4x8	250000-2000000						
Ground Taps			#12-#4/0			250000-2000000						
Lightning Arrester Ground Conn.			#1/0									

Preference Should be Given to Underscored Conductors Used in Multiple if Necessary.
Conductor No. 8 B&S. and Smaller Should be Rubber Insulated for the Voltage of Circuit.
Conductor No. 6 B&S. and Larger Should be Varnish Cambric Insulated for the Voltage of Circuit.
*Use Non Metallic Conduits for These Conductors
**Use Only As a Last Resort. Use Non Metallic Conduit and Ground Lead Sheet at One Point Only.
All Cables 750000 Cir. Mil. and Larger Should Have Rope Core. Essential For A.C. and Advantageous For D.C.
Types and Sizes of Conductors and Their Use in Power House Wiring.

*Construction Engineering Department, General Electric Co., Schenectady, N. Y.

(c) Surface resistivity.
(d) Area and nature of radiating surface.
(e) Velocity of air currents over the surface.
(f) Temperature difference.

Obviously, a heavily insulated conductor for high voltage should be given a lower current rating than another conductor of the same size with less insulation, since heat is more readily dissipated in the latter case due to a lower temperature drop through the insulation and consequent greater difference at the surface. The conductor with thicker insulation, on the other hand, presents a greater surface to the cooling air, thus to some extent neutralizing its effect as far as heat emission from the conductor is concerned.

It is equally obvious that a well ventilated conductor can carry a greater current than a poorly ventilated one for the same temperature rise, all other conditions such as size, thickness of insulation, etc., being equal. Conductors used for conduit wiring, therefore, should be given a lower rating than when used for opening wire.

All of these conditions have been considered in the preparation of Tables II and III, which give the current rating for conductors under different conditions of installation. Table I is intended to show the type of conductors used for different methods of wiring.

Direct Current Wiring

Direct current wiring generally resolves itself into a simple problem of providing conductors of sufficient cross sectional area to carry the current without undue heating. Several conductors in parallel may be arranged in the most convenient manner to suit conditions, the only considerations being the dissipation of the heat emitted and the effects of short circuits. Ventilation must be provided for the former and rigid clamping for the latter.

The current distribution under certain conditions between 12 stranded tubular conductors of copper, 1 in. inside diameter, 2.12 in. outside diameter, each of 2,000,000 cir. mil. cross-section, is shown in the following tabulation for three different methods of interlacing. Four conductors in multiple per phase have been used in a 3-phase, 60-cycle, 5000-v. circuit for 4620 amp. per phase. The currents are expressed in per cent. of normal currents in a perfectly balanced circuit which should be $4620/4 = 1155$ amp. Conductors are spaced 5 in. on centers horizontally and vertically.

CURRENT DISTRIBUTION WITH VARIOUS CONDUCTOR ARRANGEMENTS

Arrangement (1) Phase		Phase	Current Per Cent
a	0 0	a	80
b	0 0	b	100
c	0 0	c	122
a_1	0 0	a_1	122
b_1	0 0	b_1	100
c_1	0 0	c_1	80
Arrangement (2) Phase		**Phase**	**Current Per Cent**
a	0 0	a	67
a_1	0 0	a_1	139
b	0 0	b	105
b_1	0 0	b_1	105
c	0 0	c	139
c_1	0 0	c_1	67
Arrangement (3) Phase		**Phase**	**Current Per Cent**
a	0 0	a	100
b	0 0	b	100
c	0 0	c	100
c_1	0 0	c_1	100
b_1	0 0	b_1	100
a_1	0 0	a_1	100

TABLE II. CURRENT CARRYING CAPACITIES OF INSULATED CONDUCTORS FOR APPROXIMATELY 30 DEG. C. TEMPERATURE RISE

Size of Conductor	Open Wiring							Conduit Wiring													N.E.C. RATING		
	Single Conductors					2 or 3 Cond. Cable		Size	Single Conductors									Size	Size	2 or 3 Conductor Cables			Size	Table A	Table B	Table C
Max.Voltage	750	750	3500	3500	16000	750	15000	Of	750	750	750	750	750	3500	3500	15000	15000	Of	Of	750	15000	15000	Of			
Max.Current	1300	1600	175	1300	1300	550	550	Conduit	360	1075	175	675	1075	675	1075	675	1075	Conduit	Conduit	550	175	360	Conduit			
Insulation	Rub.	V.C.	V.C.	V.C.	V.C.	Rub.	V.C.		Rub.	Rub.	V.C.	V.C.	V.C.	V.C.	V.C.	V.C.	V.C.			Rub.	V.C.	V.C.		Rub.	V.C.	Other
14 B & S																								20	25	25
12 B & S																								25	30	30
10 B & S	15	15				8			15		15									8				35	40	50
8	35	35				25			35		35									25				50	60	70
6	50	70	70		50	35	50	1/2"	50		70			50		50				35	50			70	85	90
4	70	110	110		70	50	70		70		110			70		70		1-1/2	1-1/4	50	70			90	110	125
2	110	150	150		110	70	110	3/4"	110		150			110		110			1-1/2	70	110		3	125	150	200
0	150	175	175		150	110	150		150		175			150		150				110	150			150	190	225
00	175	225		175	175	150	175	1"	175			175		175		175			2"	150	175		3-1/2	225	270	325
0000	225	290		225	225	175	225		225			225		225		225		2"	2-1/2	175		175		275	330	400
300000	290	360		290	290	225	290		290			290		290		290				225		225	4	325	390	500
400000	360	450		360	360	290	360	1-1/4"	360			360		360		360				290		290		400	480	600
500000	450	550		450	450	360	450	1-1/2"		365		450		450		450		2-1/2	3	360		360	4-1/2	450	540	680
600000	580	675		580	550	450	550	2"		450		550		550		550			3-1/2	450						
750000	675	775		675	675	550				550		675		675		675		3	4"	550						
1000000	775	900		775	775			2-1/2"		675			675		675		675								650	780	1000
1250000	900	1075		900	900			3"		775			775		775		775	3-1/2								
1500000	1075	1300		1075	1075					900			900		900		900	4						850	1020	1360
2000000	1300	1600		1300	1300			3-1/2"		1075			1075		1075		1075	4-1/2						1050	1260	1670

Current Carrying Capacities of Insulated Conductors for approximately 30° C Temp. Rise
Abbreviations. Rub. = Rubber Covered. V.C. = Varnished Cambric.

Alternating Current Wiring

In a.c. wiring proper consideration must be given to the effects of mutual inductance, skin effect, heating of adjacent steel members, etc., as well as to heat dissipation and effects of short circuits. Mutual inductance is usually neutralized appreciably by interlacing of phases, either by using triple conductor cables in multiple or by reversing rotation of phases in the several single conductors. The best method of interlacing depends on the distance between conductors and the effect of external magnetic fields, such as in adjacent steel members.

The result would be appreciably different for other spacings. Where large single conductors are used in multiple, therefore, it becomes necessary to study each individual case on its merits.

Skin effect is neutralized by using hollow conductors, such as tubes, pipes or hemp core cables.

Heating of adjacent steel members need be considered only in connection with conductors carrying exceptionally heavy currents or when a complete loop of relatively short perimeter surrounds the conductor. No general rules are available to determine this heating under such conditions. Each suspicious case must, therefore, be investigated.

Type and Sizes of Conductors

Solid bare wires in sizes No. 6 to No. 4/0 B. & S. tubes and bars, are used for open wiring carried on insulators when the conductors can be protected from accidental contact by elevation, by barriers or by screens. For relatively low current values it will generally prove less costly to use these tubes in preference to wires, since a tube of equivalent metal cross section is stiffer than the wire and, therefore, permits greater spacing of insulator supports.

TABLE III. CURRENT CARRYING CAPACITIES AND SPACING BETWEEN CENTERS OF SUPPORTS FOR COPPER TUBING AND GALVANIZED IRON PIPE, BASED ON APPROXIMATELY 30 DEG. C. RISE

	Copper		Galvanized Iron Pipe	
Size of Tubes and Pipes	Capacity in Amperes	Spacing of Supports	Capacity Amperes	Spacing of Supports
3/4" OD x 11/16" ID	150	7 Ft.		
15/16" OD x .776" ID	300	8 Ft.		
1-5/16" OD x 1.084" ID	500	10 Ft.		
3/4" STD. WT. IP.S.	475	10 Ft.		
1" STD. Wt. I.P.S.	600	12 Ft.	150	12 Ft.
1-1/4" STD. Wt. I.P.S.	750	14 Ft.	200	16 Ft.
1-1/2" STD. Wt. I.P.S.	850	16 Ft.	225	18 Ft.
2" STD. WT. I.P.S.	1050	18 Ft.	275	21 Ft.
2-1/2" STD. Wt. I.P.S.	1400	20 Ft.	350	24 Ft.
3/4" E.H. WT. I.P.S.	600	10 Ft.		
1" E.H. WT. I.P.S.	750	12 Ft.	200	13 Ft.
1-1/4" E.H. WT. I.P.S.	950	14 Ft.	275	16 Ft.
1-1/2" E.H. WT. I.P.S.	1150	16 Ft.	300	18 Ft.
2" E.H. WT. I.P.S.	1450	18 Ft.	350	21 Ft.
2-1/2" E.H. WT. I.P.S.	1650	20 Ft.	450	24 Ft.

Current Carrying Capacities and Spacing Between Centers of Supports for Copper Tubing and Galvanized Iron Pipe Based on Approximately 30°c Rise and Max. .07" Deflection Per Ft. of Span When Loaded With 1/2" Thick Coat of Ice.
O.D. = Outside Diameter. STD.WT.I.P.S. = Standard Weight Iron Pipe Size.
I.D. = Inside Diameter. E.H. WT. I.P.S. = Extra Heavy Weight Iron Pipe Size.

Used in a-c circuits, tubing has the additional advantage of more even current distribution in the metal due to the neutralization of the skin effect, which in wires causes a greater current density in the outer layers. Where extraordinarily large currents have to be provided for, the conductors should preferably be made up of several bars in parallel properly protected and suitably arranged for ventilation and transposed for current distribution. A single bar will carry greater current per square inch of cross section for the same temperature rise than several bars mounted close together, since all surfaces of the single bar are better exposed to the cooling air. For this reason the rating per unit of cross sectional area must be decreased as the number of bars increases.

Bare copper tubes and galvanized iron pipes are generally used in outdoor installations for relatively high voltage connections of low current. Iron pipes, when used, should have clamp fittings of alloy instead of threaded fittings, to avoid corrosion at joints. In Table III will be found the current-carrying capacities of copper tubes and iron pipes of various sizes as well as the usual spacing between supports.

When several bars in parallel are used, they should be so arranged as to resemble as nearly as practicably possible a large diameter tube with thin walls which fundamentally is the best type of conductor, considering heat dissipation by the surrounding air, the effects of mutual inductance and the skin effect. Figure 4 gives the current carrying capacities for approximately 30 deg. C. rise of several bars in multiple spaced as shown.

Available standard supports and local conditions to a great extent predetermine the practical arrangement of bars to be adopted for large current values.

Stranded bare cables are used in all sizes for grounding connections and in sizes larger than 4/0 B. & S. for extra high voltage connections where a large diameter is desirable in order to avoid corona losses and when it is found more convenient to support them by means of strain and suspension type of insulators. Whenever possible, however, tubes or pipes mounted on rigid insulators should be used for such connections.

The heavier ground connections and busses should preferably be made of copper strip or bar to which the smaller wires used for taps to the equipment may be more easily connected.

Insulated solid wires in sizes No. 8 B. & S. to No. 4/0 B. & S. are used for open wiring on insulators when conductors can not conveniently be isolated by elevation, barriers or screens.

Stranded insulated cables in all sizes are used for conduit wiring. For conductors larger than No. 4/0 B. & S. they are also used in open wiring when not properly protected by elevation or enclosures. All insulated conductors must, however, be protected from mechanical injury.

Types of Insulation

Insulations generally used for power house wiring are rubber and varnished cloth tape. Rubber is used on wires and cables No. 8 B. & S. and smaller for 750 v. and less. Varnished cloth tape is used for No. 6 B. & S. and larger conductors for all voltages, and for smaller conductors carrying current above 750 v.

Conductors called upon to withstand exceptionally high temperatures should be insulated with asbestos tape or braid, mica tape or porcelain beads. Asbestos tape- or braid- insulated conductors are generally used for open wiring between dial plates and rheostats where they are exposed to the radiant heat from the rheostat. In power house wiring it is seldom necessary to resort to mica tape or porcelain beads. Bare conductors protected by enclosures are to be preferred.

Rubber and rubber compounds withstand the effects of moisture better than other classes of insulation used. When conductors are exposed to moisture, it is better practice to use the proper insulation as determined by size of conductor and voltage and to protect the insulation as described later.

Paper insulation is essentially used for high voltage underground distribution cables. It will withstand higher temperatures than rubber or varnished cloth but requires greater care in installation. It has, so far, found little application in power house or substation wiring.

All bare conductors must be protected from accidental contact by isolation, either by elevation or enclosures.

Conductors of various voltages are considered protected by elevation when at heights of

	for
7 ft.,	750 v. or less.
7.5 ft.,	2,500 v. or less.
8.0 ft.,	7,500 v. or less.
9.0 ft.,	30,000 v. or less.
10.0 ft.,	70,000 v. or less.
12.0 ft.,	100,000 v. or less.
14.0 ft.,	Above 100,000.

Enclosures commonly used are compartments, barriers, screens and guard rails.

Insulated conductors are essentially used for conduit wiring. At ends of runs the conductors are often carried in trenches or troughs. This makes the conductors inaccessible; trouble in one conductor may be communicated to others and dust and dirt will collect around the conductors and endanger operation.

Precautions to Prevent Damage to Cables

To protect the insulation proper from wear and tear in handling before and during installation of cables, when not otherwise armored, a single or double braid, or tape and braid, is applied as an outer covering.

Insulation on conductors used in open wiring should be protected by a flame-proof finish to make it less liable to damage from nearby conductors or combustible matter. Flame proofing, being a conductor for electric current,

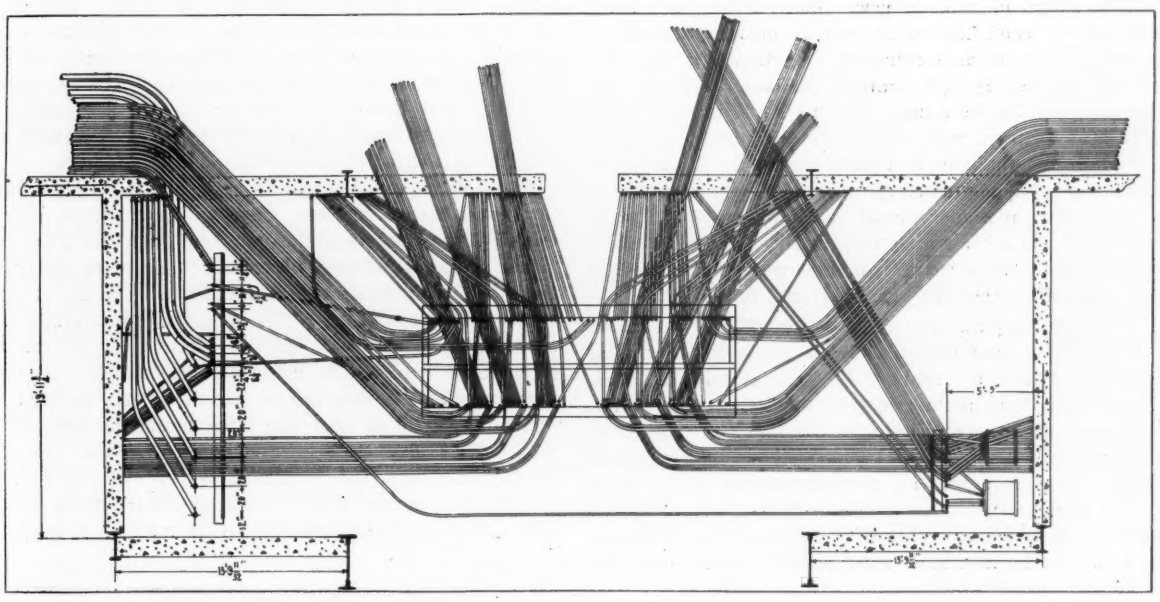


FIG. 1. TYPICAL CONDUIT LAYOUT AT CONTROL BOARD IN A LARGE HYDRO-ELECTRIC STATION

some distance beyond the end of the conduit and must then be treated as bare, i.e., carried on insulators and properly protected from mechanical injury.

Location and Arrangement of Ducts and Cable Runs

Conduit wiring embedded in the floors and walls of buildings has the advantage of being concealed except for short lengths at the ends, and of confining local breakdowns to the conductor or conductors in one conduit. Conduit runs thus embedded, may be run in the shortest available path between end points, thereby reducing lengths of conductors to a minimum. To facilitate heat dissipation, it is good practice to arrange duct runs in tiers not more than two ducts wide. This will permit air circulation on at least one side of each duct.

If no air spaces are left between tires, but a great number of ducts are laid close together, heat will accumulate, particularly around the central conductors, causing dangerous temperatures.

Cable runs in open wiring should, whenever possible, be located where they will be well ventilated and so as not to obstruct access to one another or to other equipment.

All conductors should be kept away from other heat sources, such as steam pipes, smoke flues, hot water pipes and hot air ducts.

Conductors should not be bunched together and run must be stripped back a sufficient distance from terminals to give the necessary insulation for the voltage of the circuit.

Insulated cables used in conduit wiring should be protected from moisture, either by weather-proof paint or by lead covering. Paint may be used for conduit wiring in dry locations where the conduits can be so arranged that occasional condensation is drained off as formed.

In wet conduits the insulation should be protected by a lead covering. Any undrained conduit should be considered wet even if installed in apparently dry locations, the reason being that condensate will form from time to time and accumulate in the conduit.

Lead covered single conductors used in a-c. circuits have an induced current flowing in the sheath, which materially increases the temperature rise, particularly on 60-cycle circuits. This type of protection is, therefore, not to be recommended in such cases. For the same reason, single conductor braided cables should not be run in metal conduits.

The sheath currents can be materially reduced by insulating the sheath and grounding at one point only but in this case a potential will be maintained at other points; the further from the grounded point the greater the potential, which may reach dangerous magnitude.

Cases may occur where it becomes necessary to protect the ends of the sheaths from accidental contact. There is also a possibility of the lead sheath's separating and a high voltage being impressed on the ungrounded section. This being dangerous to life, the insulation of the lead sheath from ground is not to be recommended except in special cases.

It is often preferable to use triple conductor cables for 3-phase currents, several cables in multiple if necessary. The paralleling at the ends can generally be taken care of by means of a miniature bus arrangement, such as shown in Fig. 3.

Splices and Joints

The length of runs in power house wiring is almost invariably so short that splices can be entirely avoided,—an exceedingly desirable condition. Terminals at the ends are best applied by first tinning the bared ends of the conductor and the terminals, then partly filling the vertically held terminal with hot solder and slowly inserting the conductor, making sure that the solder is still well above melting point temperature when wholly inserted. A slight amount of solder should be allowed to run over to make sure that any air or foreign matter is removed before allowing the joint to cool. It is imperative that cable ends and terminals be perfectly clean before tinning.

Lead sheathed cables on circuits above 200 v. have shown a tendency to puncture at the ends of the sheath. This is best prevented by ending the lead in suitable end bells or potheads, which provides extra insulation at such points. The application of end bells, as the making of all cable joints, requires great care. The methods of application depend to some extent on the construction of the joint. A few essential points to be observed are: not to cut insulation when removing the lead jacket or outer covering, or to injure the insulation when belling out the lead; that any insulating sleeves which may be used are properly placed and held and that the compound filler is sufficiently hot to insure penetration and to expel air or foreign matter.

Conduits and Fittings

Fiber conduits are less costly than metal and may be used to advantage for all runs which can be completely imbedded in concrete from end to end or otherwise adequately protected from mechanical injury. They require great care in installation, however, and are easily displaced or injured during the pouring of concrete. They are essentially used for long straight runs and for single conductor cables carrying alternating current.

Metal conduits are more commonly used in power plants because of their greater ruggedness. The ends may be projected from the concrete or brick surfaces, thus protecting the conductors at their most vulnerable point. Joints are readily tightened and, for exposed work, metal conduits need little consideration, so far as protection from mechanical injury is concerned, though they must be painted from time to time to prevent corrosion.

Ends of all conduits should be sealed with hollow rubber cones, oakum or clean waste with compound to prevent as far as possible the entry of dust and dirt, oil, grease or small particles of metal. This precaution will also reduce condensation to a minimum. The use of condulets, which are designed for all sizes and in almost all conceivable shapes, will not only provide a convenient receptacle for the sealing compound but will give the wiring a neat and workmanlike appearance. An inexpensive method used by at least one large power company is to separate the conductors for a short distance back into the conduit and bring them out on a flat surface side by side between two semi-circular wedges of treated wood driven into the ends of the conduits. This method of bringing

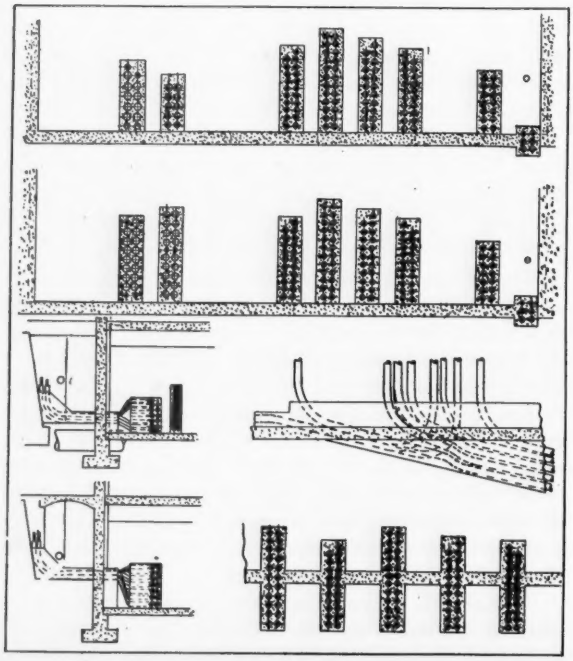


FIG. 2. EXAMPLES OF WELL VENTILATED DUCT LINES AS INSTALLED IN MODERN POWER STATIONS

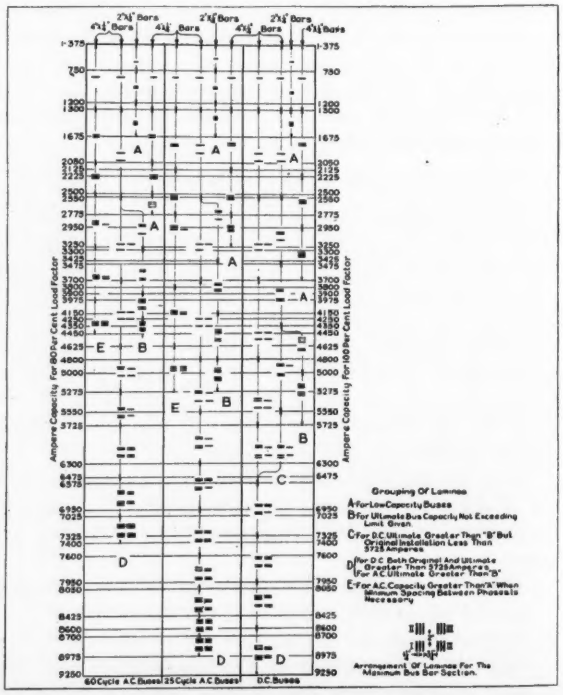

Grouping Of Letters
A For Low Capacity Buses
B For Ultimate Bus Capacity Not Exceeding Limit Given
C For D.C. Ultimate Greater Than "B" But Original Installation Less Than 3725 Amperes
D For D.C. Both Original And Ultimate Greater Than 3725 Amperes For A.C. Ultimate Greater Than "B"
E For A.C. Capacity Greater Than "A" When Minimum Spacing Between Phases Is Necessary
Arrangement Of Letters For The Maximum Bus Bar Section.
60 Cycle A.C. Buses
25 Cycle A.C. Buses
D.C. Buses

FIG. 4. CURRENT CARRYING CAPACITIES FOR APPROXIMATELY 30 DEG. C. RISE OF SEVERAL BARS IN MULTIPLE

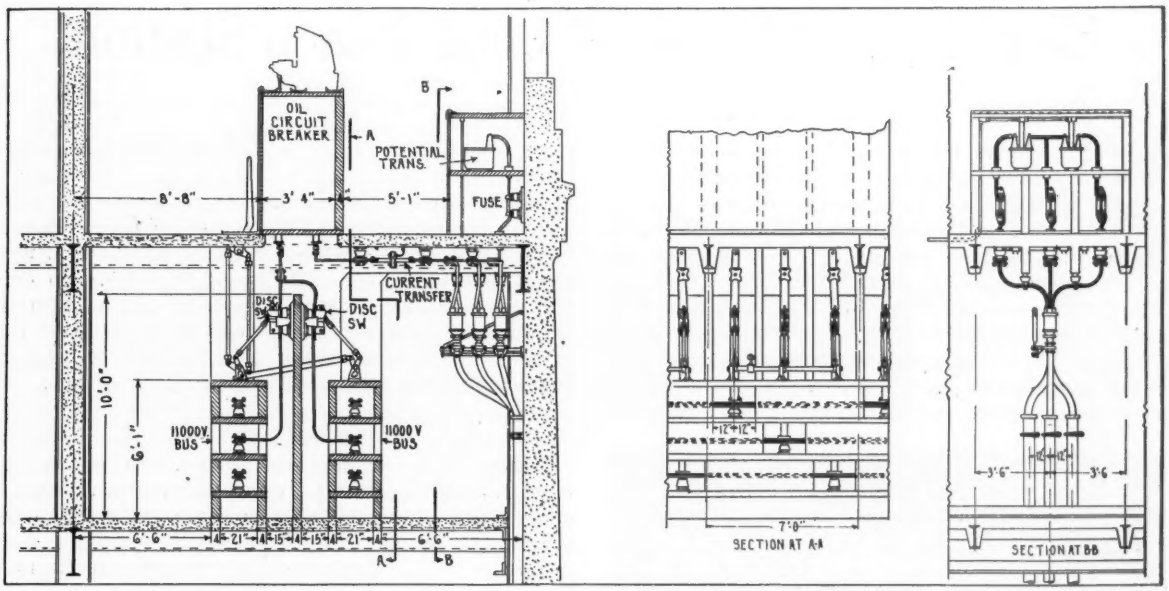


FIG. 3. METHOD OF PARALLELING 3 TRIPLE CONDUCTOR 500,000-CIR. MIL. CABLES AT OIL CIRCUIT BREAKERS

the conductors out does not provide as effective a seal, but occupies less space than condulets.

The inside of conduits must present a smooth surface so as not to injure the finishing coat of the cable. Thus, scales and burrs must be removed from each length of conduit and all joints must be tight to prevent sand and cement from entering and forming ridges. Immediately after pouring the concrete and before pulling in the cables, the conduits should be swabbed out.

Wiring Materials

Manufacturers are often handicapped in filling orders for wiring materials because sufficient information is not submitted with the order. The following tabulation might serve as a handy reference for prospective purchasers when compiling such information as will enable manufacturers to determine the character of material best suited to the conditions:

Wire and Cable

Character	Information Required
Size	Complete rating of circuit or machine, including overload guarantees. Maximum ambient temperature. Length of run. Permissible voltage drop.
Solid or Stranded	Open or conduit wiring, or partly both.
Special Stranding	If extra flexibility is desirable.
Number of conductors in cable	Nature of circuit; i. e., d.c., 1-, 2- or 3-phase, a.c., or control.
Insulation and finish	Voltage of circuit. Open or conduit wiring. Protected or exposed wiring. Wet or dry conditions.
Amount	Length of run.

Conduits

Character	Information Required
Material	Embedded or exposed wholly or partly. Nature of current in conductors.
Size	Outside diameter of cable. Max. length of unbroken run. Number of bends.
Amount	Length of run.

Insulator Supports

Character	Information Required
Size	Voltage Max. stress to which exposed in turn depending on distance between conductors and max. instantaneous short circuit current.
Fittings	Size and shape of conductor. Available mounting; i.e., flat surface, pipes or structural steel supports, and size thereof.

A SHORT COURSE meter school for electric meter employes in Western Pennsylvania, West Virginia and Eastern Ohio, will be given by the Carnegie Institute of Technology from May 4 to May 9, 1925, according to an announcement. The school will be conducted in cooperation with the Meter Division of the National Electric Light Association for the special benefit of the power and manufacturing companies affiliated with the Meter Division of the Association. The course is being planned to accommodate about 50 students, although the announcement emphasizes the willingness of the Institute to enroll practically anyone interested in the work. No tuition fee will be charged to any of the students. A series of about 12 lectures by representatives of the power and manufacturing companies and the manufacturers of meters has been tentatively arranged. In addition, there is to be an exhibit of meters arranged by the meter manufacturers.

Electrical Features of Long Beach Station

Electrical Auxiliaries at New Pacific Coast Plant Supplied by Separate Shaft Auxiliary Generators

AMONG the most interesting of recent power developments on the Pacific coast is the construction of the Long Beach Steam Plant No. 2 near Los Angeles, by Stone & Webster, Inc., for the Southern California Edison Co. This company operates some 20 hydroelectric generating stations in the Sierra Nevada and San Bernardino Mountains with an installed hydro and supplementary steam generating capacity of approximately 400,000 kw. including 22,000 kw. of emergency capacity installed in 1924. During the past two years, however, southern California experienced a serious shortage of water which reduced the

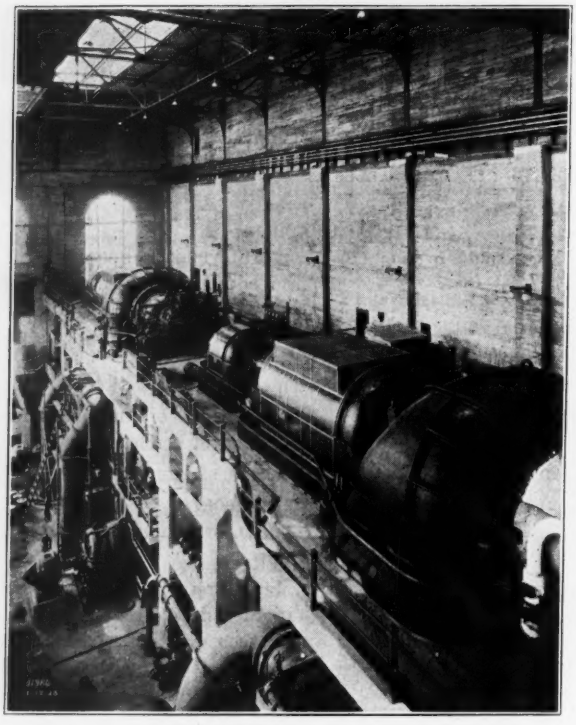


FIG. 1. INTERIOR OF THE TURBINE ROOM SHOWING TWO 37,800-KV.A UNITS

generating capacity of the system considerably. It was this water shortage that induced the company to consider the building of an addition to its facilities for steam generation of electrical energy, and towards the close of 1923, Stone & Webster, Inc., of Boston, Mass., was engaged to design and build a new 70,000-kw. steam generating plant at Long Beach, about 20 mi. from the center of Los Angeles. This plant was to be known as Long Beach Steam Plant No. 2.

This plant is now being completed and two generating units have been on the line for some time.

Before taking up in detail the design of the electrical features, it may be of interest to describe briefly the general features of the plant. The station consists of a boiler and turbine room in one building, and a switch house with the transformers located between. The arrangement of the boiler room and turbine room affords excellent light and ventilation throughout and places the auxiliary equipment in the turbine room where it is accessible to the crane hooks.

Eight boilers are installed. Each of these is provided with 15 burners capable of burning either natural gas or fuel oil with quick change-over facilities. Both oil and gas is received through underground pipelines. To prevent the possibility of back pressure or accumulation of incompletely consumed gas, in case of stoppage of the induced draft fans, the admission of fuel into the furnaces is automatically cut off when a fan ceases to operate.

Generating Units

Electricity is generated at 11,000 v. 50 cycles by two 3-phase, 38,889 kv.a., 90 per cent power factor, turbo-generators using steam at 375 lb. pressure and a total temperature of 700 deg. F. These machines are star connected and their neutrals are solidly grounded through oil circuit breakers.

In addition to the main units two auxiliary generators, each rated at 4000 kv.a. 70 per cent power factor, 3-phase,

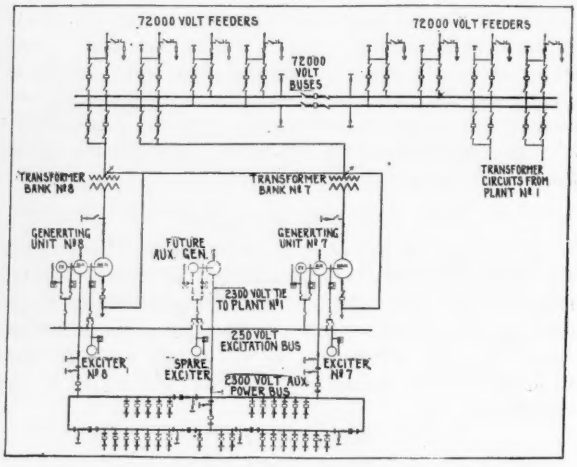


FIG. 2. SINGLE LINE WIRING DIAGRAM OF ELECTRICAL SYSTEM AT LONG BEACH NO. 2

50 cycles, are provided for supplying 2300-v. current to the motor-driven auxiliaries throughout the plant. These auxiliary generators are on the same shaft with the main generator, thereby obtaining the same high turbine efficiency as the main generating units.

The main and auxiliary generators are each provided with a closed system of air circulation and with fin type tubular coolers supplied with salt water. Fire protection is afforded by carbon tetrachloride extinguishers connected to the air ducts and by water piping in the generator end bells. A smoke detecting system is also provided which allows a continuous inspection of a representative sample of discharged air from each generator.

Excitation current for each main generator is furnished by a 175-kw. turbine-driven exciter but the auxiliary generators are equipped with 45-kw. direct-connected exciters.

The exciting current for both main and auxiliary generators is 250 v. and the system is so arranged that in case of a failure of a 45-kw. exciter, the 175-kw. exciter will carry both the main and auxiliary generator of that unit. As a relay for one or both of the 175-kw. exciters, a motor-driven 350-kw. exciter is provided. The exciter circuit breakers are non-automatic except in case of reverse current. The field breakers are also non-automatic but are arranged to trip open immediately after the generator breakers are opened in case the balanced relays are called upon to operate. All excitation breakers are controlled from the main control board in the switch house.

The Auxiliary Power System

As stated previously, power for the auxiliaries, which are practically all motor driven, is supplied by auxiliary generators mounted on the same shafts with the main generators. The arrangement permits utilizing the high efficiency of the main turbines, yet avoids any electrical connection of the auxiliary system with the main power system. Reserve auxiliary power is available through a 2300-v., connection from plant No. 1 a short distance away and provision has been made for the installation of a future reserve auxiliary generator if necessary. The neutrals of the auxiliary generators are ungrounded in order to decrease the likelihood of interruptions on the auxiliary power system.

Distribution of auxiliary power is effected through the use of the sectionalized ring bus connection shown in the single line wiring diagram, Fig. 2. As may be noted, the two generators feed into this ring at practically opposite sides, with provision for the connection of a future unit midway between the two. Sectionalizing circuit breakers are placed in this ring at suitable points so that in case of trouble, certain sections can be isolated.

The switchboard for this system is of the oil truck type and is located in the basement of the boiler room. The breakers for the generators and bus sections are controlled from the main control board in the switchhouse, while the feeder breakers are hand operated. In general, a feeder serves two motors, either of which may trip the feeder breaker by operation of its individual relays. The motors are so grouped on the feeders and on the ring bus, that the retirement of any feeder or of any bus section will not seriously affect complete operation of the plant.

In addition to the 23,000-v. system for supplying the large motors, a 440-v. system is provided for the smaller motors. The 440-v. current is obtained from two duplicate banks of transformers on separate feeders from the ring bus and is distributed to the smaller motors by means of two 440-v., 3-phase switchboards. Each bank of transformers is of sufficient capacity to carry the total motor load. The feeders from the two boards parallel each other throughout the plant, so that by means of double throw switches at the motors, any motor may be connected to either board, or, in other words, an entire transformer bank with its distribution board and feeders may be shut down without affecting the operation of any of the motors.

All motors are push button controlled. The buttons are mounted where most convenient for operation and the magnetic control panels are located in convenient groups to minimize wiring and facilitate maintenance. Brush shifting and slip ring motors are used where speed adjustment is necessary, and squirrel cage motors elsewhere. The squirrel cage motors are started at line voltage and are especially constructed for this purpose, those larger than 7½ hp. having double squirrel cage windings. Most of the motors restart automatically after a temporary lapse in the supply voltage, those which have adjustable speed, returning to the speed at which they were set.

The lighting system is 220/110 v. single phase and is fed by two duplicate, full capacity transformers. The two lighting distribution switchboards can each be connected to either transformer, so that either of the transformers may be retired without reducing the illumination of the station. A selected few of the lighting outlets are designated as emergency. These are fed from special busses which are normally connected to the lighting transformers, but upon failure of this supply, are automatically transferred to the storage battery. All switching is done by local wall switches, the cabinets merely acting as fuse

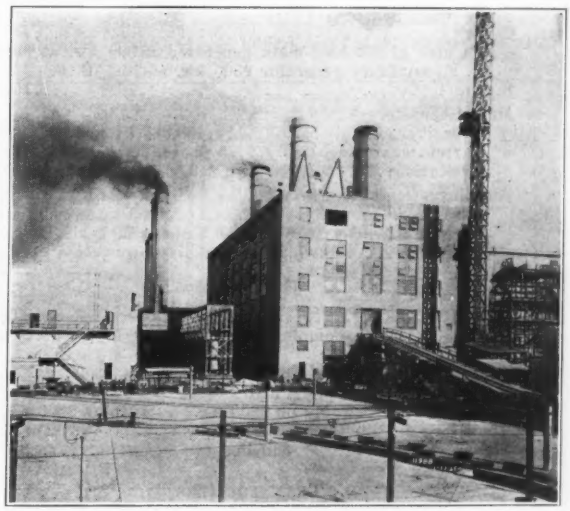


FIG. 3. EXTERIOR VIEW OF STATION SHOWING SWITCH HOUSE ON THE LEFT AND TRANSFORMERS AT THE CENTER. BOILER HOUSE AND TURBINE ROOM ON THE RIGHT. LONG BEACH STEAM PLANT NO. 1 CAN BE SEEN IN THE BACKGROUND

points and located so as to minimize wiring. The only exception is in the turbine room where the cabinets are controlled magnetically by wall switches and cabinet branch switches are provided to select the degree of illumination as required. The full cabinets provide sufficient illumination for erection and maintenance while about half this amount is sufficient for operation.

The turbine room is lighted by high capacity industrial type prismatic glass fixtures mounted above the crane. Double cast-iron brackets with Monox spherical globes and small lamps are provided on the columns to enhance the appearance of the room. The condenser room and boiler room and most of the switch house are lighted by R. L. M. reflectors and marine type guarded brackets with frosted outer globes. The latter are especially well adapted to the switch house where practically all of the lights must be placed on the walls. The switchboard room is provided with a type of semi-indirect fixture having a very small downward component.

Main generator leads are carried through tunnels under the boiler room to instrument transformer compartments at the rear of the boiler house and thence outdoors to the transformers. The transformers are single phase, each

Data on Electrical Equipment in Long Beach Steam Plant No. 2

General

Location.....Long Beach, Calif.
Character of service.....Base load power and light
Capacity, present building.....70,000 kw. at 90% P. F.
Capacity, ultimate.....70,000 kw. at 90% P. F.
Boiler house .....196 by 109 ft.
Turbine room .....207 by 67 ft.
Switch house .....207 by 78 ft.
Designed and constructed by.....Stone & Webster, Inc.

Turbo-Generators

Maker.....General Electric Co.
Number 2
Type .....
Single cylinder, axial flow, impulse, direct connected to main generator, to auxiliary generator and to exciter for auxiliary generator.
Capacity .....
Turbine 37,800 kw., main generator 35,000 kw. at 90% P. F., auxiliary generator 2800 kw. at 70% P. F.
R.p.m. 1500
Main Generators—
Capacity.....38,889 kv.a., 35,000 kw.
Current characteristics.....3 phase, 50 cycle, 11,000 v.
Excitation.....150 kw., 250 v. by separate exciter
Auxiliary Generators—
Capacity.....4000 kv.a., 2800 kw.
Current characteristics.....3 phase, 50 cycle, 2300 v.
Excitation....45 kw., 250 v., by direct-connected exciter

Exciters

Maker	General Electric Co.	
Drive	Combination drive	Motor drive
Number	2	1
Capacity	175 kw.	350 kw.
R.p.m.	1470	1000
Voltage	Motor 2200 a.c. Generator 250 d.c.	Motor 2200 a.c. Generator 250 d.c.
Steam pressure	350 lb.	.....

Transformers

Main Power—
Manufacturer.....General Electric Co.
Type.....Outdoor, forced oil cooled
Number installed.....2 banks of 3 each and 1 spare
Rating.....13,000 kv.a., 50 cycle, single phase
Connection .....
....11,000 v. delta to 72,000 v. Y, grounded neutral
Station Power—
Manufacturer.....Wagner Electric Corp.
Type.....Outdoor, oil insulated, self-cooled
Number installed.....2 banks of 3 each
Rating.....200 kv.a., 50 cycle, single phase
Connection.....2300 v. delta to 460 v. delta
Station Lighting—
Manufacturer.....Wagner Electric Corp.
Type.....Outdoor, oil insulated, self-cooled
Number installed.....2 transformers
Rating.....200 kv.a., 50 cycle, single phase
Connection...2300 v. to 230/115 v., 3 wire, single phase

Breakers and Switches

72,000 v. Oil Circuit Breakers—
Manufacturer.....General Electric Co.
Type.....FHK-39-48-YB, 3 pole, single throw
Number installed .....
.....24—400 amp. (with 2 additional for spares).
2—600 amp.
Used for .....
.....72 kv. bus ties, transformer and feeder circuits
Rupturing capacity.....1,250,000 kv.a.
11,000 v. Oil Circuit Breakers—
Manufacturer.....Westinghouse Elec. & Mfg. Co.
Type.....E-16, single pole, single throw
Number installed.....2
Used for.....
Grounding the neutral of the 38,889 kv.a. generators
Rupturing capacity.....11,000 amp. at 11,000 v.
Disconnecting Switches—
144—400 amp., single pole, 72,000 v., single throw, hook stick operated, for use with lightning arresters and circuit breakers.
24—400 amp., single pole, 72,000 v., single throw, hook stick operated, provided with grounding blades for use with feeders.
12—600 amp., single pole, 72,000 v., single throw, hook stick operated, for use with bus tie circuit breakers.
2—1500 amp., single pole, 11,000 v., single throw, hook stick operated, for use with generator neutral circuit breakers.

Switchboards

Main Control, Instrument, Relay, and Exciter Switchboards—
Manufacturer.....Westinghouse Elec. & Mfg. Co.

Type	Control	Bench
	Instrument	Vertical
	Relay	Vertical
	Exciter	Vertical

Number installed—
1 benchboard —6 sections for Plant No. 1 control.
5 sections for Plant No. 2 control.
1 section for Plants Nos. 1 and 2 turbine signal system.
1 vertical board—6 sections for Plant No. 1 instruments.
5 sections for Plant No. 2 instruments.
1 section for Plants Nos. 1 and 2 turbine signal system.
1 vertical board—6 sections for Plant No. 1 relays and recording instruments.
5 sections for Plant No. 2 relays and recording instruments.
1 section for Plants Nos. 1 and 2 totalizing curve drawing wattmeters.
1 vertical board—4 panels for Plant No. 1 exciter, control and instruments.
1 vertical board—3 panels for Plant No. 2 exciter, control and instruments
2300 v. Switchboard—
Manufacturer.....Westinghouse Elec. & Mfg. Co
Type .....Truck
Number of panels—
3—4000 kv.a. generator panels.
2—1000 kv.a. feeder panels for feeders to Plant No. 1.
5—bus section panels.
26—station feeder panels.
1—spare interchangeable feeder panel.
440 v. Switchboards—
Manufacturer.....Westinghouse Elec. & Mfg. Co.
Type .....Vertical
Number .....
2 switchboards of 9 panels each. Each switchboard consists of 1 transformer panel and 8 station feeder panels.
250 v. Excitation Switchboards—
Manufacturer.....Westinghouse Elec. & Mfg. Co.
Type .....Vertical
Number .....
2 switchboards, 1 consisting of 8 panels with remote controlled breakers for main exciter No. 7, spare exciter No. 9, auxiliary exciter No. 7, and field circuits of main and auxiliary generators No. 7; and 1 switchboard consisting of 7 present and 3 future panels with remote controlled breakers for main exciter No. 8, auxiliary exciter No. 8, future house generator exciter, and field circuits of main and auxiliary generator No. 8 and future house generator.
230/115 v. Station Lighting Switchboards—
Manufacturer.....Westinghouse Elec. & Mfg. Co.
Type .....Vertical
Number .....
2 switchboards, each consisting of 1—500 amp., incoming transformer panel, 1—12 circuit normal lighting panel, and 1—12 circuit emergency lighting panel.

rated at 13,000 kv.a. and are connected 11,000 v. delta to 72,000 star. The neutrals are solidly grounded and connected by heavy conductors directly to the grounded neutrals of the generators. The spare transformer is placed between the two banks and arranged to be easily connected to replace any one of the six without moving any of the transformers. The transformers are provided with oil conservators and are cooled by forcing the oil through surface coolers supplied with salt water. Each transformer has its own oil pump and a spare pump is arranged to start automatically in case any pump should stop. Positive provision is made to maintain the oil pressure in the coolers always higher than the water pressure, thus avoiding possibility of water leaking into the oil.

Switch House

The switch house, a reinforced concrete structure, plans of which are shown in Fig. 2, contains the 72,000-v. busses and switch gear for both Plant No. 1 and Plant No. 2, thus delivering the entire 72,000-v. output of both plants the switch house and extended upward in conduits to the control and instrument boards. All control, operating, and instrument busses, as well as cross connections between panels, are located in the terminal boxes and carefully segregated by barriers, thus greatly simplifying the wiring on the switchboards.

In addition to the usual complement of meters and relays, a special "answer-back" turbine signal system is provided for giving instructions to the turbine and boiler room attendants in both plants. Automatic load indicators with demand pointers are provided in the turbine and boiler rooms. The plant telephone system centers at the operator's desk in the switchboard room.

A 100-amp., 8-hr. lead acid storage battery of 60 cells, is provided for emergency lighting and the operation of switching equipment, valves, signals, and other vitally important devices. The capacity is sufficient to carry the maximum emergency load for a period of one-half hour. The battery is located in a room on the first floor while the control and distribution board and the two duplicate

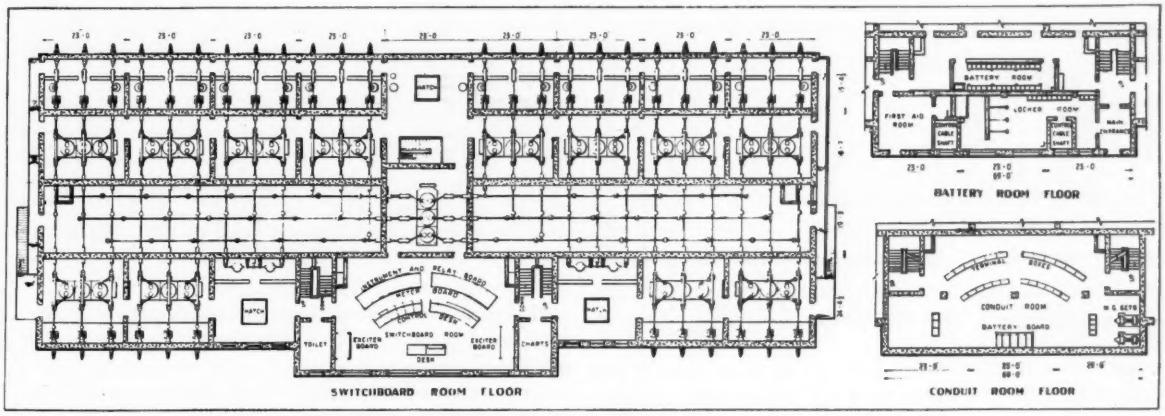


FIG. 4. SWITCH HOUSE PLANS

over eight outgoing feeders. Duplicate 72,000-v. sectionalized busses are provided, one on the first floor, the other on the second floor. Two oil circuit breakers with disconnecting switches are provided for each transformer and feeder circuit. The oil circuit breakers are all piped to purifying equipment on the first floor and storage tanks in the yard. Outdoor type equipment is used in addition to the housing to minimize leakage and eliminate flashovers which might otherwise result from deposit of salt bearing moisture which is prevalent in the neighborhood during certain seasons of the year.

Control of all main equipment and circuits in both Plant No. 1 and Plant No. 2, as well as in the switch house, is centralized in a radial type control desk located in the switch board room on the second floor of the switch house. Behind and parallel to this desk is a double vertical board mounting the meters, instruments, and relays. The exciter control boards face each other at opposite ends of the control desk. The boards on the right side of the room control Plant No. 1, while those on the left side control Plant No. 2.

The control and instrument wiring, entering the switch house in lead covered cables by way of underground fibre duct lines from both plants, pass through terminal boxes located in the conduit room directly below the switchboard room. Here the leaded cables terminate and the wiring is distributed and combined with corresponding circuits from charging sets are located in the conduit room. The charging motor generators are each rated at 15 kw., 140 v. This capacity is sufficient so that one machine can carry the normal load and charge the battery at normal rate, and the rated voltage is low enough to give stable operation with the battery floating on trickle charge.

Power Plants Grow in Western States

DURING 1924 additions of 478,403 hp. were made to the capacity of electric service companies in eleven western states, which is 15 per cent increase over the total at the end of 1923.

It is planned to add 554,531 hp. during 1925 of which 449,531 hp. will be hydroelectric and the rest steam.

Some of the plants put in in 1924 were Gorge Creek at Seattle, Oak Grove at Portland, Leevining Creek of the Southern Sierras, Soda Springs of the Utah Power & Light and El Dorado of the Western States Gas & Electric Co. New plants for 1925 will include Pit River No. 3 of the Pacific Gas & Electric Co., Moccasin River for San Francisco in the Hetch-Hetchy development, Pit River No. 4, Cutler Plant on the Bear River of the Utah Power & Light, Yale site on the Lewis River of the Northwestern Electric Co. and a plant at Horse Mesa on the Salt River, Ariz., for the Water Users' Association.

Factors in the Design of Steam Piping Systems

Pressure Drop, Radiation. Relative Location of Equipment, and Reliability Are Among the Most Important Factors in Steam Piping Design. By C. C. Hermann

IN A PREVIOUS article* on this subject the writer discussed at some length the effect of leaky joints and pipe bends on economy. In the present article I shall take up pipe lengths and pipe sizes. A long pipe through which steam is flowing is comparable with a sandy stretch through which a small stream is flowing. The water in the stream is large at the source but as it proceeds through the sand it grows smaller and smaller until at last the water ceases to flow, having been all taken up by the sand. The steam within the pipe at the source next to the boiler contains a definite amount of B.t.u., but as the steam moves

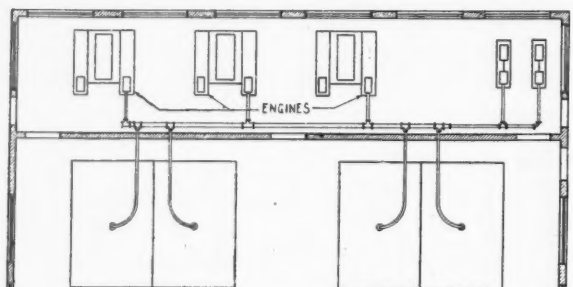


FIG. 1. BACK TO BACK PLAN OF ARRANGING BOILER AND ENGINE ROOM

onward through the pipe this heat is dissipated through the pipe walls until at a point near the end there is nothing but warm water. The heat placed in the steam has disappeared.

Steam piping is a matter of steam distribution in which there are several factors that must be taken into consideration. The first of these is the unit to which the steam is supplied. For pulsating requirements such as a steam engine of the reciprocating type the pipe size must be larger than for a constant flow such as supplying a turbine. This is because a higher velocity may be used for turbine supply. Velocities of 15,000 ft. per min. may be maintained where high pressure superheated steam is generated whereas 8000 ft. per min. is generally high for steam pressures without superheat. Steam temperatures of around 600 deg. F. are not uncommon in large central stations and the future no doubt will bring the industrial plants of the country to a fuller realization of the saving possible by the use of higher pressures and superheat. This feature of the problem practically segregates the industrial plant on the one hand and the electric central-station on the other. Whereas electric central-station work has taken on a more or less uniformity of design we find in the isloated stations much diversity and variation in the piping scheme. Almost every case requires separate and individual consideration; however, the chief object of all piping schemes is to conduct the fluid in the safest and most economical manner to the operating unit. This unit may be a prime mover, drying unit, heating coil or other steam consuming apparatus.

*Attention to Piping Details Saves Steam, Page 239, February 15, 1925, issue.

In the smaller plant we find extremely large steam headers employed with all boiler and engine leads connected to this one header. A low velocity is obtained in the header at the expense of installation. In the more modern plant we rarely find a steam header over 18 in. in diameter and in many cases the pipe leading from the header to the prime mover is built one or two sizes smaller than that called for by the engine builder. It is the practice in the latter instance to incorporate a large receiver just ahead of the throttle in order to provide a volume of steam several times as large as that of the high pressure cylinder in order to provide a constant and full supply of steam at the throttle as well as to provide a cushion that

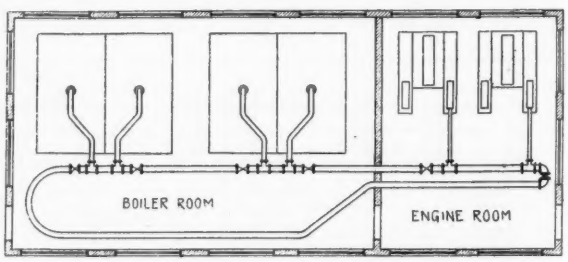


FIG. 2. END TO END PLAN OF BOILER AND ENGINE ROOM ARRANGEMENT

will absorb the shock of the cutoff. The pipe between this receiver and the throttle is invariably full size.

Pressure Drop Is Important Factor in Design of Piping System

The controlling factor in the design of any piping system is the pressure drop. The engineer is chiefly concerned with the proper size of pipe that will deliver the required volume of steam at the point of consumption at a predetermined pressure drop. The pressure drop permissible varies with the steam requirements and condition of the steam. For reciprocating steam engines using saturated steam the drop may run from one-half to one and one-half pounds per hundred feet whereas in superheated steam practice with turbines as the prime mover the drop may run as high as three and one-half pounds per hundred feet. In the latter case the steam velocity may be around 15,000 ft. per min. as compared with 8000 or 9000 ft. per min. in the former. The permissible pressure drop in either case must be dependent upon the length of the delivery pipe. For long pipes the drop must necessarily be lower than for short runs in order to deliver the steam to the prime mover at as high pressure as possible. Another factor that must be taken into consideration is the resistance of the dry pipe, valves, fittings and the superheater in the case of superheated steam. The delivery pipe loss is in a measure only a small portion of the total loss. On the other hand, high drops in the pipe lines may cause the total pressure drop to exceed the permissible limit with economy as a consideration.

In the smaller plant the pressure drop is a factor that need not, ordinarily, be given very accurate consideration. It is better to err on the side of pipe lines slightly large for

the service than to have them small. In the large plant, however, we find that the installation costs increase very rapidly due to the large size of the pipes and fittings and here extreme accuracy in these matters makes a considerable difference in dollars and cents in the initial cost.

Large pipes cause a corresponding increase in radiation which is also a loss so that the designer of a pipe system must take into consideration the saving of radiation with small pipes and a saving in pressure loss with large pipes. As at once assumed, there is a turning point or, as it might be called, a neutral axis between the two considerations which give the most efficient results. It is too bad, therefore, notwithstanding the fact that numerous tests have been made in the laboratory and on systems in actual use, that there is no reliable information relative to the actual behavior of steam in the piping. Practically all available rules commonly used in pipe system designs require some adjusting to the existing conditions surrounding the design.

Relative Arrangement of Boiler and Engine Room

Wherever practical the piping system should eliminate all long pipes from the consideration of first cost as well as operating economy. This phase of the design is directly concerned with the relative arrangement of the generating and consuming units. Briefly, there are three types of arrangement that may be chosen from; namely, back to back, end to end and double deck. In the back to back plan the boiler room and engine room are located side by side with the back of the boilers and the back of the engines separated by a single wall. This arrangement is shown in Fig. 1. Whether or not this system is best suited for a given installation depends upon future planning of the operations. For example, referring to Fig. 1, which shows a single line of boilers, if an addition to the power plant were to be made in the future and expansion lengthwise were not possible a double row of boilers would be in order. There would be a firing aisle between the boilers and in this case the main headers for the additional boilers would be carried across the building to the engine room. This design places the stack, if of substantial construction, preferably at one end of the building for each row of boilers. These points are not in the nature of objections but are given to point out the expansion problem connected with every project.

Figure 2 illustrates the end to end plan in which the boiler room and engine room are strung out in a line. This type of construction necessitates long headers and considerable piping in the engine room which is an objection in many cases. Comparing this plan with that of the back to back construction we find many points in favor of the back to back plan. In the latter most of the piping is located in the boiler room, steam lines are of minimum length and the general arrangement is preferable, due to economy of space as well as lower cost of building construction. The end to end construction is adopted only where the former cannot be carried out, due to local conditions.

Figure 3 illustrates the double deck plan of construction. Where ground space is limited this construction is considered the solution of the problem; however, this is about the only advantage that can be claimed. Apparent advantages are more than offset in the increased cost of building construction. The building must be constructed substantially enough to support the boilers on the upper deck. One set of bunkers and ash handling equipment, however, serve both decks cutting down the length of these to one-half that required by the single deck boiler room.

Of the three systems mentioned the first is by far the most common. This is particularly true in the West and Central West where the pinch of space has not been so acutely felt to date. In the large cities of the East the double deck plan is found occasionally and the end to end plan quite often. This is due, in a measure, also to the fact that the Western stations are of more recent design in many cases than the Eastern stations.

In my observation of power plants and piping systems the single header system predominates. This is primarily due to three factors of consideration, namely, low first cost, simplicity of installation and flexibility with regard to extensions. In an effort to shorten up the main header as much as possible many plants have run the branch pipes

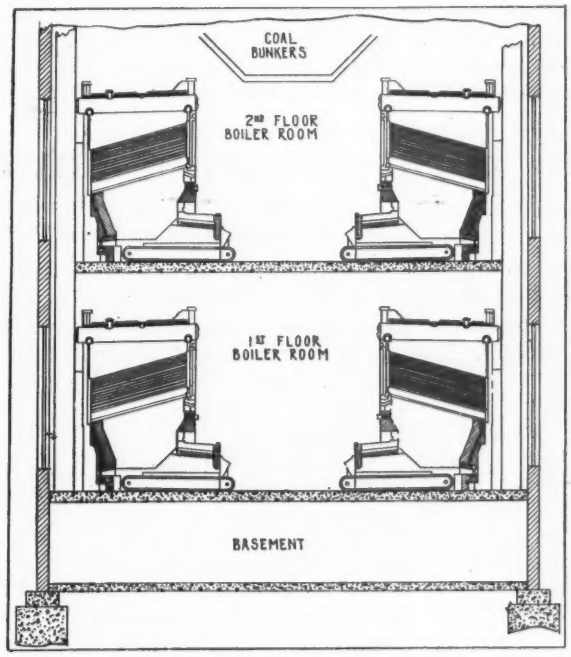


FIG. 3. THE DOUBLE DECK PLAN

of all boilers to a central point. This accomplishes the desired effect, however, complicates conditions when expansion is necessary.

In large central stations we find segregated units in which the prime mover is supplied with boilers and piping entirely separate, with the exception of cross connections to insure continuous operation, from other units. In such installations each unit is generally provided with separate coal and ash handling equipment as well as boiler feed pumps and piping.

Value of Duplicate Systems

Only occasionally do we find a duplicate system of piping in effect. Experience has taught that the additional expense entailed by duplicating the headers is unwarranted and that in such cases where capacity fluctuates to any appreciable degree the investment may be better applied in supplying headers of different sizes to accommodate the variation of capacity. There is a general tendency toward better piping and connections, fittings and covering in a single header. For example gaskets of higher quality and

turned high grade flanges and bolts are being used in place of the ordinary companion flanges and sheet packing. These are details that determine continuity of operations without the double cost of an inferior installation.

The design of any piping system must take into consideration the expansion and contraction of the pipe. The pipe must be free to move throughout its entire length or buckling is apt to occur. Some means must be incorporated in the pipe lines to take care of the expansion and contraction. The method utilized may be either swing joint or by slip joint. A third method not commonly found is known as the tension and compression system. In this latter the header is placed between anchorages and when the pipes are at normal room temperature the pipes are in tension and when working under the steam temperature they are under compression.

The most satisfactory method is by the swing joint method incorporating long radius bends in the pipe line. For tunnel construction this is not always practical, therefore, the slip joint comes in for practical use. The pipe must be anchored to prevent separation at the joint and the pipe next to the slip joint must be properly supported in order to insure free working of the pipe in the stuffing-box. Swing joints must be provided with screw fitting for the free swinging in taking care of the expansion and contraction in the main pipe. Where space will not permit long radius bends, straight pipe may be used by incorporating a screw joint. The length of pipe provided for the swing should be long enough to provide free movement without excessive bending of the pipe, as when the pipe passes through a wall sufficient space should be provided around the pipe to give free movement.

We have confined our discussion thus far to the piping between prime movers and the boilers. These pipes must be sufficiently insulated to avoid radiation losses. It is generally conceded without much argument that insulation of a serviceable and efficient make pays for itself in a short time with steam saved. Insulation should not stop with the steam pipes but should also be applied to the boiler, steam dome, all valves and fittings as well as receivers, etc. Fully 95 per cent of the heat loss may be prevented by proper application of any of the reliable commercial coverings.

Inspection of Power Plant Equipment

Complete Records of Inspection of Power Plant Equipment Should Be Kept on Forms Printed Especially for That Purpose

IT WOULD BE practically impossible to lay down either a set of rules or a schedule by which inspection and maintenance for plants of various types and sizes could be controlled. They are largely problems of individual analysis and depend upon experience with the specific equipment of which the engineer is in charge.

We might take for example, the internal inspection and cleaning of a group of boilers. Obviously, it would be impractical to have all the boilers down at one time. Therefore, some schedule must be adopted as a starting point so that each boiler will receive that attention which it is anticipated it will require. If there were four boilers in the plant, it might be well to open up one every two weeks, thus inspecting each boiler once every two months.

After a reasonable time on this schedule, it may be found that this period of two months may be increased to three months or it may have to be shortened because of bad water conditions. Again, a change in conditions may occur, which will necessitate a change in the schedule. For instance, a new water treating plant may change the boiler cleaning period from two months to six months or even longer. This is an economy in operation, which should be accredited to the estimated cost of equipment to be used for a contemplated improvement in the quality of the feed water.

The whole problem resolves itself into one of plant economics. Enforced shutdowns are expensive not only as far as the power plant is concerned but also to the departments which use the power or those who purchase power. On the other hand, the power plant operator is not justified in putting in too elaborate and costly a system of inspection and maintenance. He must keep his operating expenses as consistently low as possible without assuming undue risks which will result in enforced shutdowns.

Investigation by the N. E. L. A. brought out the rather interesting fact that among the utility operating companies there is a surprising lack of agreement as to the method of scheduling or planning major overhauling or maintenance. In hydraulic plants, the one rule which seems to be quite universal is that such work should be carried on when possible during the low flow season, or if such a season does not exist, then the work should be carried on at the time of the least load demand.

Some companies have no prearranged schedule. It is often found that yearly, semi-annual or even monthly inspections are made, which do not keep equipment out of service more than a short time. These inspections will show when a piece of equipment should be taken out of service for a period long enough to make major repairs. Thus no productive time is lost until the inspection has shown the unit is in a condition which must be corrected. At the other extreme are those companies which lay down schedules of maintenance and inspection which are adhered to rather closely. It is, of course, not to be expected that such a schedule can be maintained without any variation whatever. Either or both of the schedules may have to be changed from time to time as improvements are made in design or construction.

This condition often occurs in a new plant where the first year or two of operation enforces changes in order to avoid as far as possible the "weakest link," which, though small in itself, may require the shutting down of a whole unit. Capacity and economy records are often valuable because they afford a means of keeping a close check of the condition of a unit and thus indicate the necessity for work which may not have been scheduled.

Standard Forms Are Valuable

Of great importance for the successful operation of any system of inspection and maintenance is: first, an adequate variety of blank forms on which the inspector can record his findings; second, an accurate system of recording the labor hours required for maintenance; third, a storehouse record of the material used. The two latter records are often not fully appreciated, but the fact remains that they form one of the strongest arguments which an engineer

can advance when submitting a proposition to the management for new or additional equipment. The cry is often heard that the management cannot be made to spend money for power plant improvements. That is just exactly as it should be unless facts can be presented to break down that resistance. Business men are accustomed to talking in dollars and cents and you have to talk in their language if you are going to impress them. A record of high maintenance costs will go a long way towards getting rid of that old faltering pump and replacing it with one which you know will prove more economical in operation.

One large company which operates a great many electric plants provides for two inspections each year, that is, one every six months. This work is done by a regular inspector who reports to a central office. He is aided in his work by a number of printed forms which enable him to submit complete and uniform reports. In addition to these forms, the inspector is often provided with a list of items, thus avoiding the possibility of some important point being omitted from his final report. In going over the report of this inspector, great care is taken to note the things which he considers require immediate attention and also anything which in his opinion would tend to improve the efficiency of operation. These points are carefully noted on the forms and in the text of the report which are then brought to the attention of those who are most interested.

The foregoing might appear to pertain to a group of plants; however, after a little thought it can readily be seen that inspection and maintenance problems for a number of plants must be built upon the requirements of the individual plant, for after all that is where the problem actually occurs and where its solution must be applied. For that reason it is also important that the routine inspection of a plant be reduced to a system so that a check may be made as to whether or not the inspection has been made and what steps have been taken to overcome defects.

How One Company Inspects Traps

This can be accomplished only by having a definite mode of procedure and by keeping adequate and complete records. To illustrate how one company has found it advisable to keep records, one form was made out to cover only the inspection of steam traps. Each trap had been given a number and had been stenciled with that number. Once every two weeks an inspector made the rounds and noted the number of the trap, the date of inspection, condition of packing, gaskets and connections and its operation. Any repairs needed were carefully noted. This report was signed and sent to the master-mechanic whose duty it was to see that the maintenance work reported was carried out.

By comparing one report with another, it was not a difficult matter to find those traps which were giving the most trouble and to determine the character of the trouble which often led to the replacement of a trap which was not worth trying to keep in good operating condition.

It is never amiss to inspect, in as thorough a manner as is possible, any piece of equipment which is about to be warmed up or cut in on the line. A defect may be caught at the last minute. An instance of this kind was recently experienced in a steel mill engine room. At stated periods, it was required that wire brushes and gasoline be used to remove the accumulation of grease and dust from the hub, spokes and rim of every flywheel in the plant. A 20-ft. wheel had been cleaned on Sunday and reported in good condition. Monday morning the engineer noticed, while warming up the engine, what appeared to be a crack in the wheel. A closer inspection revealed that he was right and the unit had to be taken out of service immediately.

Just because a complete system of inspection is in practice in a power plant is no reason why every employe about the place should not consider himself an inspector and constantly keep on the lookout for conditions which do not appear to be right. It may be that in some instances he will report conditions which are already known to exist, nevertheless he will be performing his duty faithfully and he may have the satisfaction that his interest will in most instances be appreciated.

Industrial Lighting*

By Chas. J. Stahl

IN THE PAST ten years there has developed a greatly enhanced appreciation of the value of good industrial lighting, brought about principally by the following developments:

1. Industrial research conducted by the manufacturers of lighting equipment in cooperation with central stations supplying electric service.

2. The production of better lamps and media for the efficient control of light directly to the purposes for which it is required.

3. The demand for increased production and decreased production costs.

4. The educational work of the societies and associations represented by this gathering including the Illuminating Engineering Society and others.

5. Last, but not least, the necessity of conserving the human eye under the demand for greater accuracy and the necessity for reducing the appalling number of accidents brought about by the use of powerful machines, overlapping operations and the desire for speed.

Adequate lighting results in the following benefit as set forth in a recent publication issued by the National Safety Council: Reduction in accidents, greater accuracy in workmanship, decreased spoilage of product, increased production for the same labor cost, lessened eye strain, better working conditions, less labor turnover, better order, cleanliness and neatness in the plant, easier supervision of the men.

Coincident with the changes in the general public's attitude toward the value of good industrial lighting has come a fundamental change in the attitude of the manufacturers of lighting equipment. In the past, their efforts were to sell more lamps and more reflectors with little concern as to their proper application and use. Today their attitude is to sell illumination.

Artificial lighting in industry is now regarded as the potent agent of constructive force and it is steadily exerting a greater influence and benefit upon our civilization. It is known to be of first importance in the prevention of accidents. It is a great aid in solving the problems of night traffic in our cities. The right or wrong use of lights will conserve or impair the eyesight of the younger generation which is soon to enter the great army of industrial workers. Conservation of eyesight is of great economic benefit and is an assurance of fewer needless accidents in years to come.

*An abstract of a paper read at the Baltimore Safety Conference, Baltimore, Md., Jan. 23, 1925.

Arc Welded Exhaust Steam Line

By E. W. Gallagher

JUST recently an exhaust steam line consisting of 800 ft. of 30-in., and 400 ft. of 28-in. and 24-in. pipe, in which the circular joints, saddles and angle flanges were electric arc welded, was put into service at one of the large steel mills. At first, there seemed to be some doubt among the engineers as to the advisability of arc welding this line;

FIG. 1. ARC WELDING THE PIPE ON THE GROUND

but an inspection of the finished job would convince even the most skeptical, that welding is not only practicable but desirable. The pipe for this line was furnished by the National Tube Co. and was made from $\frac{5}{16}$-in. mild steel, hammer welded, the welding being done by the Welding Equipment & Engineering Co. of Cleveland.

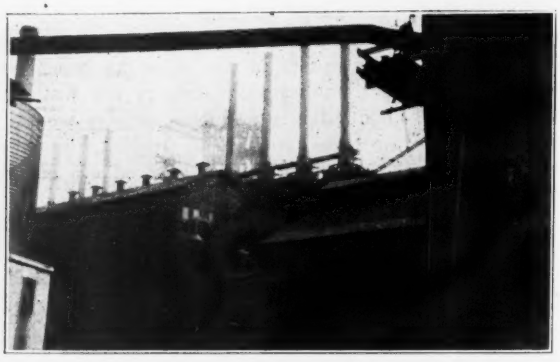


FIG. 2. MAKING FINAL WELD OF PIPE SECTION

Figure 1 shows the portable welding equipment used and the operator at work. Free flowing low carbon steel electrode $\frac{5}{32}$ in. in diameter was used in welding the circular joints and saddles and $\frac{3}{16}$-in. mild steel in welding the angle flanges. About 625 lb. of metal was deposited and the work was completed in 250 working hours, giving an average deposition of 2½ lb. of metal per hour. The fact that the welder could be easily moved from place to place by one man eliminated the necessity of handling long welding cables and aided considerably in speeding up the job.

At one time a 100-ft. section was hoisted into place by a crane. As a matter of curiosity to know whether or not the welds would withstand the strains, this particular section was first lifted by attaching the spreader immediately back of the end circular joint. This induced a tension stress of about 5500 lb. per sq. in. in the topmost fibers of the weld without any signs of failure.

Figure 2 shows the above referred to section in place and the operator making a flange weld which was not done on the ground owing to the difficulty of properly setting the flanges. Note the 48-in. stand pipe which has a welded

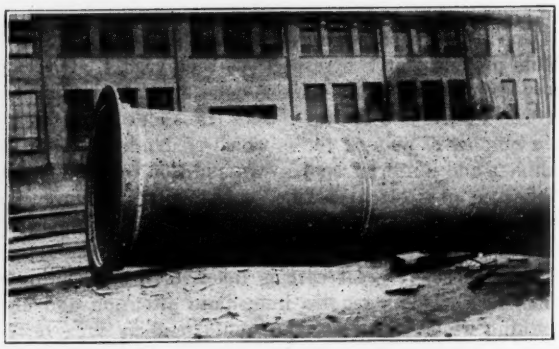


FIG. 3. ARC WELDED JOINT AT CLOSE RANGE

circular joint. A close view of a welded joint and an angle flange is shown in Fig. 3. It will be noted that the flange extends about ½ in. beyond the end of the pipe which was inside beveled 45 deg. to facilitate welding. The $\frac{5}{16}$-in. plates were beveled, sheared, rolled, and hammer welded. A number of the circular joints were welded on the inside of the pipe due to the fact that the sections lined up poorly, leaving in many places an opening of ¾ in. to be bridged by weld metal.

Figure 4 shows a flanged joint, the flanges being made of 4 by 4 by ¾-in. angle iron rolled, welded and faced.

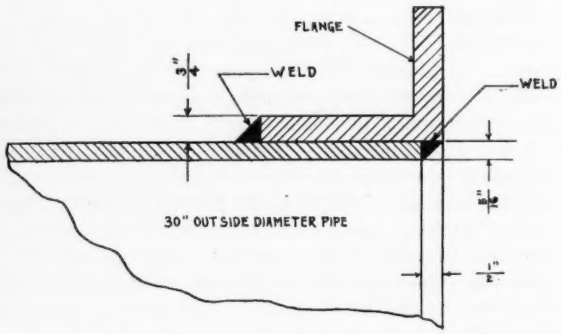


FIG. 4. ANGLE IRON WAS USED FOR FLANGES

There were seven 28-in. manholes together with numerous other take-offs, ranging in size from a 5-in. tee connection to a 28-in. branch off at 30 deg.

The advantages of welding over riveting this line may be summarized as follows:

Owing to the elimination of the internal friction due to rivet heads, welded pipe could be made 2 in. smaller in diameter, which, coupled with the lower cost of hammer weld pipe, resulted in considerable saving.

In as much as a 16-in. pipe line is to be suspended from this line, the strong, permanently reliable joints desirable were assured by welding.

Heat Loss in Flue Gas Measured by Using Economizer as Calorimeter

IN THE Feb. 15 issue, N. T. Bourke's article on flue gas loss will be found of special value to practical engineers. In most power plants, the ultimate analysis of the fuel is made at comparatively rare intervals and, except in large plants, is usually made by an outside chemist.

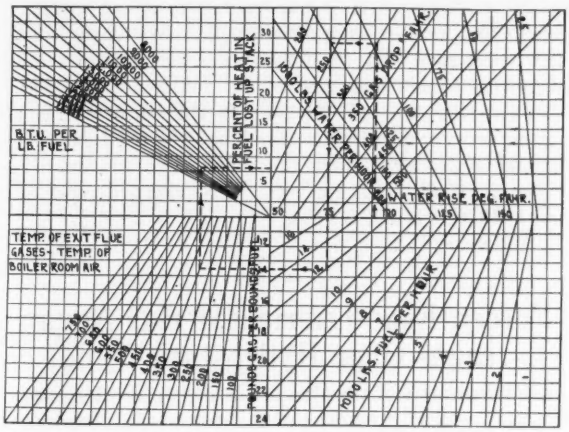

B.T.U. PER LB. FUEL
PER CENT OF HEAT IN FUEL LOST UP STACK
TEMP. OF EXIT FLUE GASES - TEMP. OF BOILER ROOM AIR
POUNDS GAS PER POUND FUEL
POUNDS GAS PER HOUR PER SQ. FT. HEATING SURFACE
POUNDS WATER EVAPORATED PER POUND OF FUEL
WATER RISE DEG. FAHR.
1000 LBS. FUEL PER HOUR

CHART FOR DETERMINING HEAT CARRIED AWAY IN FLUE GAS, USING ECONOMIZER AS A CALORIMETER

The proximate analysis may easily be made on the plant and, by means of the chart given, the fixed carbon in the fuel may be determined with sufficient accuracy from this analysis. Before dealing with another method of determining the flue gas loss, which requires neither the analysis of the gas nor the fuel, it will be well to consider one or two points in Mr. Bourke's article.

The standard formula

$$W = \frac{11\,CO_2 + 8O_2 + 7\,(N_2 + CO)}{3\,(CO_2 + CO)} \times \left(C + \frac{6}{11}S\right)$$

gives the weight of dry flue gas per pound of fuel. The water vapor in the flue gas, which is that introduced with the air, moisture in the fuel, and formed by the combustion of hydrogen in the fuel, is the cause of an unavoidable and often considerable loss, which in this case must be considered separately from that due to the heat carried away with the dry flue gas. It is also to be observed that the statement: "Owing to the presence of water vapor in the flue gas, it is impossible to have the per cent of CO_2, O_2, and CO, as determined by an Orsat to add up to 20.9 per cent, is not necessarily correct. This is only the case when the vapor in the gases condenses in the Orsat (as it will do if below a temperature of 100 deg. F., approximately its dew-points). If the gases are dried before analysis the total of these three constituents should be close to 20.9 per cent. The C in the formula is the total fixed carbon burned per pound of fuel, less that carried away with the refuse per pound of fuel.

Most modern power plants have an independent economizer to each boiler. If this should be the case, using the economizer as a calorimeter provides the most accurate means of measuring the overall flue gas loss. In the Prime Movers Committee 1923 Report of the N. E. L. A., part B, page 256, will be found a statement to this effect. The fundamental formula is:

$$w\,(t_1 - t_2) = C_p\,W\,(T_1 - T_2)$$

where

t_1 = temp. of water leaving economizer, deg. F.
t_2 = temp. of water entering economizer, deg. F.
T_1 = temp. of gases entering economizer, deg. F.
T_2 = temp. of gases leaving economizer, deg. F.
w = pounds water passing through economizer, per hr.
W = pounds gas passing through economizer, per hr.
C_p = specific heat of flue gas at constant pressure.

The specific heat at constant pressure, C_p, is here taken as 0.245, which includes a very small allowance necessary for radiation, and is more nearly correct than the value 0.24 usually assumed. The weight of gas passing through the economizer is given by:

$$W = \frac{w\,(t_1 - t_2)}{C_p \times (T_1 - T_2)} \text{ lb. flue gas per hour}$$

and dividing W by the pounds of fuel fired per hour gives the pounds of gas formed per pound of fuel. The measurements required are all simple and usually made in every-day operation; no chemical analysis of fuel or gas are required. The per cent of stack loss is then:

$$\text{Per cent stack loss} = \frac{W \times (T_2 - T_a) \times C_p \times 100}{\text{Lb. of fuel per hour} \times \text{B.t.u. per lb. fuel}}$$

where T_a = temp. of boiler room air, deg. F.

The accompanying chart will give a rapid solution of these equations, and gives a method of estimating the overall flue gas loss in every-day operation. This method, it is hoped, will appeal to engineers in charge of plants equipped with economizers.

New York. BRIAN M. THORNTON.

Area of Segment Found by Using Subtended Central Angle

FROM TIME to time there are various formulas printed in Power Plant Engineering for finding the area of a segment. The one I submit here is accurate to any degree desired. The only knowledge of trigonometry needed is the ability to find an angle from a table of natural functions when the cosine is given. Most tables give angles

to 45 deg. only. In case the central angle is over 90 deg., it must be remembered that the cosine of an angle is the complement of the sine.

If we are given R = the radius of the circle and H = the height of the segment, then E, the central angle which subtends the chord of the segment, may be found by the formula:

$$\frac{R-H}{R} = \text{Cos } \tfrac{1}{2} \text{ angle E}$$

The formula for the area of the segment then becomes

$$\text{Area} = \frac{\text{Pi } R^2 E}{360} - [(R-H)\sqrt{R^2-(R-H)^2}]$$

This formula may be worked out almost as readily as the approximate formulas and there is then no uncertainty about the percentage of error.

Pittsfield, Mass. PERCY W. BLANCHARD.

Small Plant Records Kept with Simple Apparatus

IN AN industrial plant, where power costs are likely to be an insignificant part of the total cost, it is not easy to get all the apparatus needed to tell us just what we are doing. We keep a daily record, after a fashion and, while it may not be accurate within 3 per cent, it enables us to get a fair idea of how we are drifting. We have scales for weighing coal, two turbine hot water meters, an Orsat apparatus and a sampling tank for taking 8-hour samples of the flue gas. Our draft gages are home made, but they serve fairly well. We have an 800-hp. boiler plant hand-fired by the alternate door method.

Steam is used for power, water service, process work and heating when the engine is not running. We run evaporative tests, usually 48 hr. in length, checking the time when the shop is running separate from the time it is shut down. We get the percentage of ash from weights over the whole period of the test, computed against the total coal weight.

Our scales are tested periodically and when going into a test they are balanced with the empty barrows on them. The meters were recently sent back to the makers to be overhauled and calibrated. According to their report, the error was less than 1½ per cent. We have a tolerably good method of testing them ourselves at any time. We have a tank of 22,717 cu. ft. capacity and have the boiler water piped to this. We stop the pump until the pressure in the feed line is lower than boiler pressure; then, with one man at the meter, one at the pump and one at the control cock, we run the water into the tank until it reaches the predetermined mark. When the water is shut off from the tank and the meters read, we find usually that one meter registers about 3 per cent high and the other 3 per cent low. This makes them correct when both are running, otherwise we need to deduct or add 3 per cent. We found the capacity of the tank by weighing water into it and correcting for temperature.

To find the moisture in the coal, we try to get a fair sample of it by the usual sampling methods. After crushing it, we place it in a small pie pan and weigh it to a tenth of a gram, then set it on the steam chest of the air compressor, where it is under a temperature of about 150 deg. F. for 5 hr., when it is weighed again and the percentage of moisture arrived at. This is not according to Hoyle; but as we do it the same way every time, it does very well in comparing one coal with another.

We use oil instead of water in our gas sampler. The sampler consists of two tanks made of 5-in. pipe connected to the flue gas supply in the smokebox and a steam jet for drawing the gas through the pipe until it is ready for the sampler. The oil is forced from the lower tank to the upper one by compressed air. Care must be exercised to fill the upper tank completely with oil. The oil, as it runs back to the lower tank, sucks in the sample. We sample only during the period when the shop is running, as at other times nobody trained in the use of the apparatus is around.

We get our highest CO_2 with freshly mined coal and the boilers run at normal rating. They are of the H. T. type, 200 hp. each and only 30 in. from the grates. For this reason, they simply won't stand more than 25 per cent overload, otherwise we might get better results. They are 20 yr. old and it is not desired to spend money to place them farther from the grates. We have learned that to get good CO_2, the fireman must try to throw about two-thirds of his coal back of the middle of the grates, otherwise the fire will be thin at the back. Fires are put on seven to eight times per hour, the red light of the damper regulator telling the men when to fire. The smoke box draft is 0.1 in. with the regulator damper open and 1/20 in. when it is shut.

Anderson, Ind. J. O. BENEFIEL.

Forced-Feed Lubricator Has Advantages Over Hydrostatic Type

ON PAGE 301 of the March 1 issue is a short discussion for and against hydrostatic and forced-feed lubricators. May I add my thoughts to this timely subject? What Mr. Mason says in regard to the hydrostatic type of lubricator is true.

Where there are a number of men on the job, such as shift engineers, it is a common thing for the man going off watch to fill the lubricators for the man coming on watch, who frequently forgets to turn them on. Sometimes they are not filled. Again he may turn the condenser on and forget to turn on the feed. Sometimes he will turn the feed on and never stop to regulate it to the proper feed and in a great many cases it is plugged and the engineer will not stop to find out whether it is working right or not. I have gone in on watch and found lubricators turned off and found them turned on and not working, also with the up-feed completely filled with oil so I could not tell whether it was working at all or not.

One other annoyance is the bad habit that some lubricators have of blowing out the glasses. This can in some cases be prevented by ignorant men blowing the water and what oil is left out instead of shutting the condenser and up-feed off and letting the water drain out of its own accord when the filler plug is removed. This gets the whole lubricator hot and when the cooler oil comes in contact with the glass something has to go and it is generally the glass after the pressure is turned on and you start to walk away. Sometimes it happens just as you are starting to wash up. Also when the engine or pump the lubricator is feeding is stopped, the engineer forgets to shut off the lubricator and the oil is lost.

Now with the forced-feed lubricator, we have none of these ills. We fill the tank and put on the cover and the machine does the rest. The lubricator that never runs dry and never gets dirty and never plugs up has not yet been invented. The forced-feed lubricator does not explode and scatter oil all over the place and no oil is lost by careless running over in filling. When the engine and pump it is serving stops, the feed of oil stops also. There is no pressure in this type of lubricator. It can be placed any convenient place and with big engines generally no climbing is necessary to reach it for filling.

Rochester, N. Y. R. G. SUMMERS.

Why Not More CO_2 Refrigerating Plants?

IN REPLY to the article by R. G. Summers, in the Feb. 1 issue, entitled "Why Not More CO_2 Refrigerating Plants?" I will state a few of the reasons for the general preference of the ammonia plant over the CO_2 plant.

Advantages claimed for the CO_2 machine are: it requires only a small compressor cylinder, CO_2 has no odor, it is less dangerous to life and stored goods than ammonia and it costs less per pound than ammonia.

One of the chief disadvantages is that excessively high pressures must be used on both sides of the system, making extraordinary care necessary to prevent leakage; it is necessary to test constantly for leaks, as there is no odor to indicate them as is the case with ammonia. A small leak will rapidly deplete the charge and this leakage loss usually more than offsets the difference in cost of CO_2 and ammonia.

The CO_2 machine shows an efficiency of only 85 per cent of the efficiency of an ammonia machine with cooling water at 75 deg. F. or less. With warmer water the capacity falls off rapidly.

The critical temperature of CO_2 is 88.2 deg. F. Above this temperature no amount of pressure will cause it to liquefy. This limits the condenser water temperature to about 78 deg. F., allowing 10 deg. difference between the water and the CO_2 for heat transfer. It is readily seen that the use of water much warmer than this would be impracticable. The critical temperature of ammonia being 271.4 deg. F., much warmer water can be used, thus making it possible to use it in places where the water temperature would prohibit the use of the CO_2 machine altogether.

Shamrock, Okla. H. T. SMITH.

Mending a Break in the Exhaust Pipe

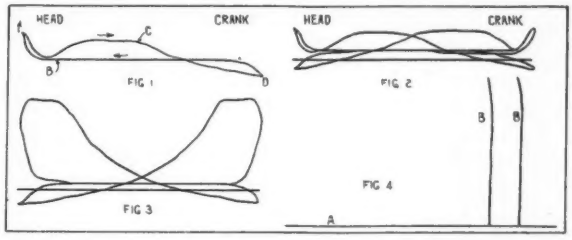
ALTHOUGH M. M. Brown's description, in the Feb. 1 issue of the method he used to repair a break in an 18-in. exhaust pipe is interesting, I fail to understand why he used, as a filler, red lead and iron filings. This mixture might form a slow-drying compound if any liquid is used as a binder, such as boiled oil. For work of the nature described, however, the red lead will shrink more or less and its expansion is different from that of iron. Of course, such a filler might give satisfactory service on an exhaust pipe where there was a very low pressure, but why use such a compound when a much better one is right at hand?

There is now on the market an extensively tested material for permanently repairing just such breaks as Mr. Brown described. I have used this material for repair jobs under many different conditions and have received satisfactory results in every case. My personal opinion is that it is not the best policy to use a doubtful article, such as red lead and iron filings, when a nationally known and tested article, such as the material mentioned, can be secured for a few cents a pound at any hardware store.

Toronto, Canada. JAMES LONDON.

Indicator Diagrams Show Slipped Eccentric

IN A RECENT case of trouble with the low pressure side of a cross-compound Corliss the card shown in Fig. 1 was taken. A slipped eccentric was suspected, especially when a diagram from both ends, Fig. 2, was taken. The plates were taken off the valve chambers and it was found that the steam valves had fully ⅛ in. lap. With the movement of the piston, on the forward stroke as the volume increases (clearance volume) the pressure diminishes and at the point B the steam valve starts to open. The piston has at this time made about one-eighth of its stroke. The pressure gradually increases and at C cutoff takes place.



FIGS. 1 AND 2. DIAGRAMS TAKEN WITH ECCENTRIC SLIPPED BACK. FIG. 3. MOVING ECCENTRIC AHEAD IMPROVES THE DIAGRAM. FIG. 4. UNTRUE MOTION OF INDICATOR ARM CAUSES ERROR

Expansion occurs from C to D, when the exhaust valve opens; this valve closes for compression after point B is passed. Diagrams in Fig. 3 were taken after the eccentric was moved ahead.

When I was taking these diagrams and making changes in valve setting, the steam line on the head end remained the same, notwithstanding the fact that the steam valve was made to open earlier. So Fig. 4, to check the indicator, was taken. The atmospheric line A was drawn and then, with the paper drum stationary, steam lines BB were drawn. Instead of being drawn perpendicular to the atmospheric line they curved near the top, showing the same fault which occurred when taking the diagrams. The spring was changed and proved OK. The steam pressure had been too high for the spring.

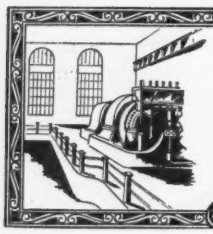
Burlington, Iowa. TOM JONES.

Washing Machines for the Power Plant

AS I WAS interested in the washing machine Mr. Carothers described in the December 1 issue, I made one and found it to be unusually satisfactory. In reading the February 1 issue, I noticed the complaint offered by A. P. Nutter as to the high cost of operating such a machine. I am wondering whether he has figured out this cost. If so, I should like to know what his figure is.

If his company is thinking of installing some such device, what, in Mr. Nutter's opinion, would be any cheaper or better? We should appreciate his idea on the subject.

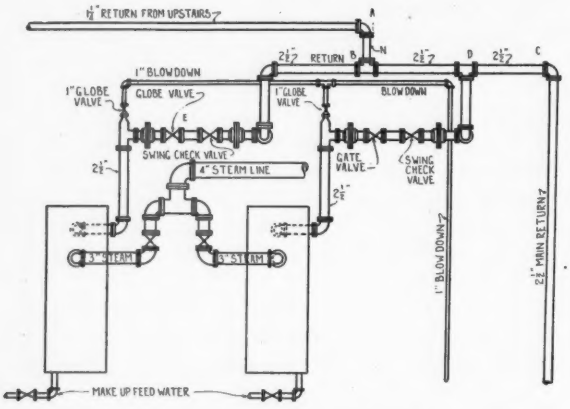
Detroit, Mich. C. NELSON.



QUESTIONS AND ANSWERS

Why Does One Boiler Take All the Returns?

We have two H. R. T. boilers, 60 in. by 14 ft., used for low-pressure heating, the return lines coming back to the boiler as shown in the sketch. No traps or pumps are used, the head of water giving sufficient pressure to put it into the boilers. The trouble is that when both boilers are



PRESENT CONNECTIONS OF RETURN LINE TO TWO LOW-PRESSURE HEATING BOILERS

operating, first one boiler and then the other will take all the returns. Can you suggest some simple and inexpensive method of preventing this? R. B. E.

Pull of Solenoid Depends on Ampere-Turns

As a part of a balanced valve device I am working on, I need a solenoid to operate on 110 v. direct current, using 1 amp., but cannot purchase one. Can I make it myself? If so, how much wire will I need to use? A. H. W.

A. You will find, on page 1599 of Mark's Mechanical Handbook, an interesting discussion of the subject of solenoids and lifting magnets, together with formulas for the design of them.

The strength of a solenoid or magnet depends not upon the number of amperes flowing through the magnet coil but upon the ampere-turns, that is, in general, upon the product of the current times the number of turns of wire through which it flows. There are, of course, exceptions to this rule, but it holds in most cases. Accordingly, it should not be difficult to design a solenoid for your purpose and to have it constructed quickly and cheaply.

In the discussion given by Marks, referred to above, the following formula appears:

$$P = (K A I N) \div L$$

in which P is the pull of the solenoid in pounds; K is a constant representing the pull per sq. in. of core per ampere turn; A, the effective area of the core; I, the current; N, the number of turns, and L, the length of the windings in inches. You did not state the amount of pull you wish this solenoid to have, but let us assume 5 lb. Let us also assume a length of coil winding of 6 in. and an effective core area of 1 sq. in. From the table given in Marks', K is 0.009. Now, putting these values into the foregoing formula, we have:

$$5 = (0.009 \times 1 \times 1 \times N) \div 6$$

from which $N = 3333$ turns.

Now we must determine the proper size wire to use. Since $E = I R$, we have $110 = 1 \times R$, from which, R, the resistance = 110 ohms. If we assume the mean diameter of this winding to be 2 in., we shall have approximately

$$(2 \times 3.14 \times 3333) \div 12 = 1740 \text{ ft.}$$

This amount of wire must have a resistance not greater than 110 ohms in order to pass 1 amp. at 110 v. Therefore, its resistance must be $110 \div 1740 = 0.0635$ ohms per ft. Looking in a wire table, we find that No. 28 B. & S. wire has a resistance of 0.064,79 ohms per ft., which would probably be close enough for your purposes.

Therefore, according to the preceding calculations, a coil of 1740 ft. of No. 28 B. & S. wire, probably double cotton covered, 6 in. long, with an effective opening through the center of 1 sq. in. cross section and the wire wound as close as possible, would probably give you a solenoid whose core would have a pull of approximately 5 lb.

It seems to us, however, that this coil would not be well proportioned. It might be better to use more current and fewer turns of larger wire in order to make the coil shorter. That, of course, depends upon the distance through which you wish the core of the solenoid to travel. In any case we have indicated above the general method by which you can figure this and, by substituting other values for those given, you can probably work out a satisfactory design.

You can probably work out the design of the core and the spool to hold the winding, since these mechanical details will depend on the apparatus on which the solenoid is to be used.

Replacing Nipples on Double-Deck Water-Tube Boiler

On a double-deck water-tube boiler, short nipples connect the upper and lower headers. How are these nipples replaced in case they give out? W. H. K.

If the headers are of the vertical type, the lower end of the upper header and the upper end of the lower header forming each section are quite close together. A 4-in. tube nipple of the proper length may be inserted through a hand hole and, by the usual method of rolling and flaring, secured into position. Some of the inclined header boilers, on the other hand, have a greater distance between the upper and lower header; that distance, in some cases, is as much as 14 in., so a nipple of proper length to unite

the upper and lower deck cannot be inserted through the handhole.

Where the distance between the upper and lower headers is over 4½ in., it is customary to use a steel collar in which the ends of two short nipples may be expanded, as shown in the sketch, thus producing a nipple of the required length. The collar is made of 6 in. or 7 in. diameter steel shafting, drilled to fit the 4-in. tube nipples

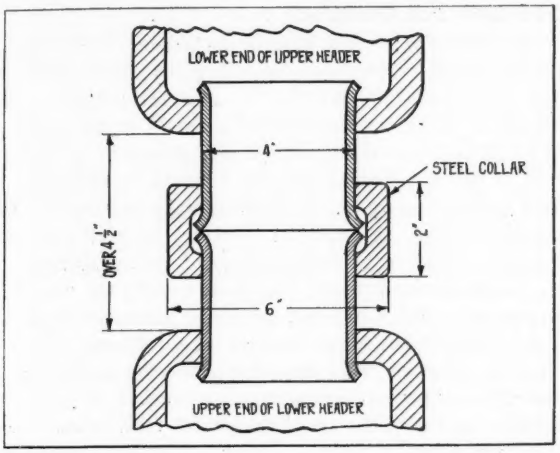


FIG. 1. SHOWING LONG CONNECTION MADE BY TWO NIPPLES AND STEEL COLLAR

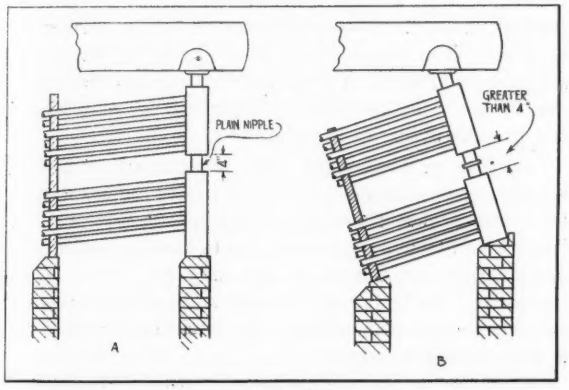


FIG. 2. A. SHORT NIPPLE IS USED WHEN HEADERS ARE CLOSE TOGETHER. B. WHEN HEADERS ARE WIDELY SEPARATED, BUILT-UP NIPPLE IS USED

and recessed so the ends of the nipples may be properly flared to secure maximum holding power. The work of flaring and expanding the nipples is done by a rolling expander designed for that particular purpose.

Expansion in Underground High Pressure Pipe Line Taken by Slip Joints

REFERRING to the discussion on expansion in an underground pipe line in the Feb. 1 issue, perhaps you will be interested in the method of meeting these conditions used by our company, as we manufacture a large number of expansion joints for this particular service.

We use a co-efficient of expansion of 0.008 in. per 100 ft. for each degree change in temperature. This corresponds to an expansion co-efficient of 0.000,006,7. This gives a total expansion of 11.97 in. for a 350-ft. line between temperatures of 70 deg. and 497.4 deg.

For 225 lb. steam pressure and 100 deg. superheat, an extra-heavy cast-iron expansion joint would be used. This joint, as manufactured by our company, will accommodate 8 in. of expansion in the 5-in. size. Two joints are all that would be required for this line.

To accommodate the expansion in long runs of pipe, we frequently furnish the double expansion joint with anchor. Such a joint is anchored in the manhole and expansion is compensated for in both directions. By the use of this joint, the number of manholes is cut down, the pipe line being anchored between manholes and expanding in both directions from the anchor. A double high pressure joint will take care of a total expansion of 16 in.

When it is desired to allow for expansion from both sides and the total expansion does not exceed the limit of a single joint, a single unanchored joint can be used in the manhole.

New York. F. A. BURG.

Steam Purifiers Cause Small Fuel Loss

WE HAVE recently installed steam purifiers in our boilers, the water removed by these purifiers being dumped by a trap into the sewer. By weighing this water and the feed water, I find that 6 per cent of the feed water is thrown away. The boilers operate at 115 lb. gage pressure, taking feed water at 212 deg. For fuel we use gas containing 965 B.t.u. per cu. ft.; we use approximately 49 cu. ft. of gas per b.hp.-hr. What is the fuel loss caused by the action of these steam purifiers? L. L. B.

A. You did not give your rate of evaporation but it can be figured from the following formula:

$$\text{Factor of evaporation} = \frac{H - L \times \frac{M}{100} - h}{971.7}$$

$$= \frac{1191 - 872 \times 0.06 - (318 - 180)}{971.7} = 1.04$$

In the above formula H equals the total heat of the steam at 115 lb. gage; L is the latent heat of evaporation at that pressure; M equals the per cent of moisture; h equals the heat of the liquid above feed water temperature. The values, as inserted in the above formula, were taken from the steam table.

Now, since the evaporation for one boiler horsepower, from and at 212 deg., is 34.5 lb. per hr., the evaporation under your conditions will be 34.5 ÷ 1.04 = 33.2 lb. per hr. for one boiler horsepower. Your boiler takes feed water at 212 deg. and raises it to 318.2 deg., corresponding to 115 lb. gage pressure. Therefore, each pound of water, in this process, absorbs 106.2 B.t.u. But at this point 6 per cent of this water is thrown away and the remainder is turned into steam at 115 lb. gage, with which we have nothing more to do. Then, 106.2 × 33.2 × 0.06 = 212 B.t.u., which are thrown away each time a boiler horsepower is generated. According to the figures you gave, the fuel supplied 965 × 49 = 47,300 B.t.u. in generating one boiler horsepower. Therefore the proportion of heat thrown away in this water discharged by the trap is 212 ÷ 47,300 = 0.004,47 or about 0.45 per cent.

EDITORIAL COMMENT

Keep Up the Interest in Safety

Accidents can be greatly reduced in number and severity if the same consideration be given to the subject as is given to the other problems involved in plant operation. Certain safety features can be provided in the original design of the plant, however, it is not to be expected that the foresight of the designer in providing safety appliances can possibly eliminate all accidents. As constructional changes must often be made, so must it be expected that further safety provisions must also be made after a plant is in operation.

This problem can be attacked from two angles, first, by a study of conditions and the application of more or less standardized safety regulations and, second, by a careful analysis of accidents as they occur. The first method depends largely upon foresight and past experience gained through the operation of other properties. It will not always suffice, however, because there are certain features of every plant which require special attention and which are not easily foreseen from the light of past experience.

It is a usual thing for a great commotion to result from an accident. This lasts a short time and it may be that lengthy reports are made on it. So far so good, but why should not that accident be studied in relation to those of a similar nature which have occurred in the past? This can be accomplished satisfactorily only if records are available and if there is sufficient interest to carry the investigation as far as it is humanly possible to do so. The true value of a piece of equipment depends not alone upon its performance today but upon its present performance as compared to that of the past. The same thing is true of the safety movement. You cannot know the true effectiveness of today's methods unless you have an accurate knowledge of what has taken place in the past and this end can be gained only through an adequate system of records which are thoroughly analyzed. Present day interest is what counts rather than a series of closed incidents.

This fact has been recognized by our government as evidenced by the calling in Washington of a national safety conference. This meeting was not called to attack a new problem but rather to gather the accumulative experience of all those agencies which have been battling independently. The first move by this conference was to gather far reaching and valuable data and information to be compiled in a report which was to be made available for wide distribution in printed form. This report has now been broadcast all over the country and through its agency it is expected that further safety work will be greatly enhanced.

This same idea should be carried out not only by a group of plants but also by the individual plant. Obtain complete data, record it, analyze it both past and present and arouse the interest of everyone who is in any way involved.

Station Auxiliaries

Reliability is the first word in the lexicon of the modern power station, taking precedence in many cases over economy and efficiency. Whether in a central station or an industrial plant, the throwing of a switch or the pressing of a button out on the line must be answered by an instant rush of power. Modern practice, with its developments of high pressure steam, air preheaters, stage heating and the bleeder turbine, has made it necessary to give also considerable attention to the reliability of the auxiliaries. It is of considerable interest, therefore, to note the care that is now being taken in selecting proper drives for them, to insure their functioning properly at all times. The increasing adoption of electric drives for the auxiliaries is one of the important developments in modern power plant design. In a way, the use of the bleeder turbine has forced this development.

Several systems of installing such electrically driven auxiliaries are in use in many of the larger central stations. In most cases, a combination of two or even three systems, one of them usually steam driven for emergencies, is in use. The report of the N. E. L. A. on this subject, a discussion of which is given elsewhere in this issue, shows that of the 33 central stations reporting, all used electrically driven auxiliaries in some form.

For this purpose, many types of motors have been developed, each suitable for the conditions under which it must work. Sometimes it is found best to drive one auxiliary with two motors, a small one to handle normal loads, and a larger one, thrown in by a magnetic clutch, to take the peaks. Controls may be automatic, proper automatic switching equipment acting with almost superhuman skill at just the right instant.

Then, too, if the auxiliaries are driven in this way, the source of power for them must be reliable. Essential auxiliaries such as boiler feed pumps must be assured of a source of power that cannot be interrupted, while the station is in operation, by disturbances in the outside system. Power from the main busses, from a separate house turbogenerator, from a generator on the shaft of the main unit, or direct from the main generator leads, may be used. However, it is obtained, the particular conditions under which the station is to operate will determine the design to give the greatest reliability.

Economy, of course, is a consideration in the large station. But overall economy at the expense of reliability is not to be considered. Steam driven auxiliaries are in some cases no more safe against interruption than those which are electrically driven, and are certainly no more economical, with their multiplicity of high pressure steam piping, exhaust lines and traps. A few of them, of course, must be kept for standby service, but in the newer stations they are surprisingly few.

Regulation Can Go Too Far

After two years spent in gathering information, the Giant Power Survey Board of Pennsylvania recently made its report to the Legislature of that state. This report included a program for legislation to meet a development in the near future which Governor Pinchot predicts will be revolutionary in its effects upon the social and industrial order. Sharp distinction is drawn between the "super power" program which is characterized as a means by which surplus power is exchanged between producing systems and the Giant Power Program which seeks the cheapest sources of power—hence the lowest rates—and creates a great pool of power from which all consumers can draw.

The Giant Power Board suggests that the means essential to the regulation and control of the industry of the state are mass production of electrical power (chiefly at the mines, where fuel is most readily accessible); the creation of a common pool of power out of which current for all uses can be taken; free access to every purchaser of power, this end to be secured by making transmission lines common carriers; the regulation by the Public Service Commission of rates, service and security issues; regional compacts between states for the interchange of current and the systematic distribution of power in the rural districts.

When this survey was started, the public was led to believe that it would be carried out somewhat along the lines of the super power survey, but covering only the entire state of Pennsylvania. If we judge from the program proposed, the real object in making the Giant Power Survey was to supply the officials of the state with data upon which to base legislation, which can be used in more extensive regulation of the public utility companies. The report indicates that its adoption should prove one of the surest safeguards against public ownership and the creation of a great unregulated monopoly.

With the Public Service Commission regulating rates, controlling bond and stock issues and having authority to compel public service companies to give service, which the law provides in most states, regulation, it would seem, is sufficiently complete to protect the public against unjust rates and insure reasonably good service which are the important points of contact between the public and the utilities furnishing power. State regulation governing power generation, distribution of loads among stations, the use of transmission lines and other engineering details of the public utility power systems can lead only to needless complications and expense which can best be handled by the companies themselves.

Off Duty

How long is a million years?

We cannot answer this question with any degree of satisfaction, but we have a sneaking hunch that it is a long, long time. It reminds us of an old Chinese legend which attempts to explain eternity. This legend tells of a mountain of pure diamond, miles upon miles in height which stands in a land uninhabited by man. Once every three hundred years, a little bird comes to this mountain and sharpens its beak on it. When the entire mountain has been worn away by the little bird's beak, only one second of eternity will have elapsed.

In our everyday life it makes little difference, however, whether we are able to form a conception of a million years or not and most of us probably are of the same opinion as the old lady who said, "it will be all the same a hundred years from now." To the astronomer searching out nature's secrets in the sky, a million years is a useful time interval, however, and he regards it much as we do the hourly divisions on our watches.

Look up into the sky some clear cold night, at the thousands of stars above you. Whether you know anything about astronomy or not you recognize certain configurations—the Dippers, the Pleiades, Orion, these are familiar to everyone. From childhood up we have observed these constellations and the unvarying relation of the stars composing them have impressed their form upon our minds. The "fixed" stars we call them because their positions do not change.

But they do move, not a single one of the hundreds we see and the thousands and millions which the unaided eye cannot see is at rest. Throughout all time they have been in motion and throughout all time they will continue in motion. Moving at tremendous velocities the stars we recognize and have known since childhood have been altering their relative position in space, but their distance is so enormous that in spite of their high velocities, we have not been able, except by means of the most refined astronomical instruments, to detect any change of position.

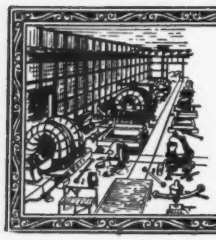
The nearest star, Alpha Centaurus, which has been referred to as the first stopping place to the left, is 4¾ light years away. A light year is the distance that light will travel in one year, moving as it does at the rate of 186,000 mi. per sec. The next nearest star is almost double this distance. These, however, are mere jumps. Most of the stars are hundreds of light years away.

Our unaided eyes reveal only a few of the stars. The big telescopes and the photographic plate in the observatories have shown us millions where we could see only thousands.

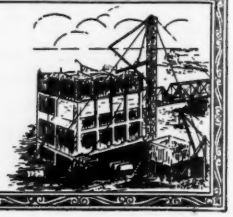
Out in California, at the Mt. Wilson Observatory, Dr. Edwin P. Hubble has revealed within recent years the existence of external universes, each similar to the lens-shaped group of stars of which our sun is an insignificant member. There are thousands of these, with the nearest so distant that it takes the light from it, a *million years* to reach us. These island universes appear through telescopes as clouds of light more or less circular and with a spi al structure. They are so remote that the very thought of their distance staggers the mind. Some of them it is estimated are a *hundred million light years* away.

A million years—a long time? Yes, perhaps to our way of thinking, but in astronomy and in the evolution of worlds it is nothing. An instant of time. In the lightless spaces of the sky where no star ever shines there are worlds in process of creation; worlds that are as yet but cosmic dust—highly rarefied gases, pushed about by minute forces of light, and that will not come into being for trillions of years; worlds that will require almost endless time before they evolve life. In the limitless spaces between the stars there are micro-organisms drifting about dormant in the almost absolute zero of space, waiting for a world on which they can settle.

Time? Time is nothing. We say time passes, but that is not true. "We pass; time stands still." In the formation of suns and worlds by cosmic evolutionary processes a million years is an instant of time. The Chinese sage who told the story of the bird and the diamond mountain no doubt realized this, but being a wise old philosopher and knowing something of the skepticism of mankind, stated his conception of time in a most conservative way.



POWER PLANT ENGINEERING
DEVELOPMENTS AND NEWS



New Substation for Northern Indiana

GREAT INDUSTRIAL CENTER NOW TIED IN WITH THE POWER RESOURCES AVAILABLE IN THE CHICAGO DISTRICT

COMPLETION OF the new substation and transmission line of the Calumet Power Co. at Aetna, near Gary, Ind., has recently been announced. Service was inaugurated Feb. 12 by the throwing of a switch, by Mayor O. P. Johnson of Gary, which will feed 50,000 kv.a. over the new transmission line into the substation at Aetna

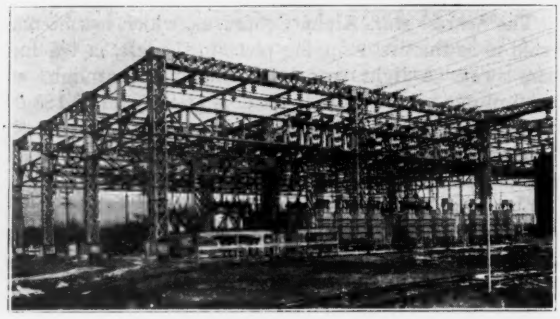


FIG. 1. DISTRIBUTION SECTION OF THE SUBSTATION IS OWNED BY THE CALUMET GAS & ELECTRIC CO.

from which radiate lines to the distribution systems of the Northern Indiana Gas & Electric Co. and the Calumet Gas & Electric Co.

The new transmission line in this development was constructed by the Calumet Gas & Electric Co. and it will be operated by the Northern Indiana Gas & Electric Co. The substation will be operated jointly by both companies. This line is constructed on a private right of way 150 ft. wide, steel-tower construction being used for the entire 16 mi. from the Illinois-Indiana state line to Aetna. The towers vary from 96 to 115 ft. in height and are erected on concrete foundations. Three 300,000 c.m. cables and a ground wire have been placed on one side of the towers. The initial capacity is 50,000 kv.a., whereas with additional cables it is expected that the ultimate capacity will be about 150,000 kv.a.

At the east end this line is connected in with similar lines which connect with the Calumet station of the Commonwealth Edison Co. and the Joliet station of the Public Service Co. of Northern Illinois. Voltage delivered to the Aetna substation is 133,000, where there are located four transformers, three of which are in regular service and the fourth is a spare. These transformers are wound for distribution line voltages of 33,000 and 13,200; the latter, however, is not used at present.

One 33,000-v. line of the Northern Indiana Gas & Electric Co. will connect Hammond, East Chicago, Indiana Harbor and Whiting with this substation. This line also will be connected with the East Chicago generating station of the Northern Indiana Gas & Electric Co. Another 33,000-v. line will connect this substation with the lines of

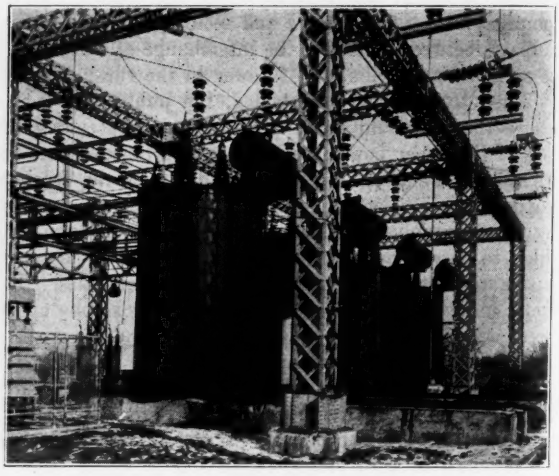


FIG. 2. THREE TRANSFORMERS ARE IN REGULAR SERVICE, THE FOURTH BEING A SPARE

the Northern Indiana Gas & Electric Co. and the Calumet Gas & Electric Co. and the Public Service Co. of Northern Illinois at the latter company's generating station at Blue Island, Ill. A third 33,000-v. line will connect Michigan City with the Aetna substation and a fourth will connect the distribution systems of Chesterton and Goodrum and other communities with this substation.

Still another 33,000-v. line runs from the substation to the new plant of the Gary Tube Co. which has contracted with the Calumet Gas & Electric Co. for electrical energy for the operation of its new plant. This makes a total of six high tension transmission lines radiating from the Aetna substation.

This development is backed by the power resources of the Commonwealth Edison Co. and other generating stations in the greater Chicago district, which are practically operated as a single unit in the generation of power. The Calumet generating station, which is connected directly with the Aetna substation, has a capacity of 187,500 kw. The power resources of the Chicago district total over 1,000,000 kw., as all the generating stations in the Chicago district are interconnected in one system. Inauguration of service from the Aetna substation makes this section of

Northern Indiana an important part of the superpower zone in and around Chicago which was described by the late Charles P. Steinmetz, as the "greatest pool of power in the world."

This superpower development in northwestern Indiana is but the first step in development of this character on a large scale in this section of the state which is expected to become, within the next 30 yr., the center of the greatest industrial and electrical development in the Middle West.

FIG. 3. LOOKING THROUGH THE STRUCTURE OF THE DISTRIBUTION SECTION

The availability of sites for large electric generating stations and the contemplated erection of superpower systems in this section, together with the natural advantages of this part of the state as an industrial center, makes possible this great development. The industrial development in this section of the state, the abundance of water for condensing purposes in the operation of large generating stations and the nearness of the Indiana and Illinois coal fields make the shores of Lake Michigan the logical location for large generating stations.

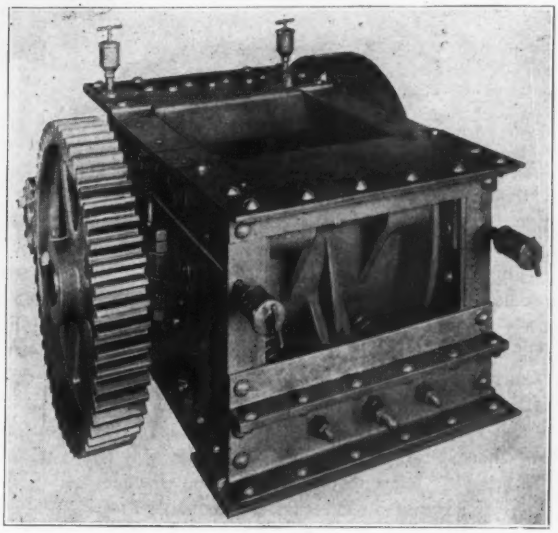
Crusher Frame Made of Structural Shapes

INCREASING efficiency of other units of the modern power plant, both large central stations and smaller industrial plants, has thrown an increasing burden upon the coal preparation equipment to furnish finer and more uniform sizing of coal.

To meet this demand, the Pennsylvania Crusher Co., Philadelphia, Pa., has recently placed on the market its new "Armorframe" single-roll crusher. In operation coal is fed to the crusher in any quantity desired. The rotating toothed roll draws the coal into the tapered opening between the roll and breaker plate, quickly reducing it to the desired size and discharging it below to the belt, elevator or direct to the bunkers. The natural agitating action of the teeth passing through the coal on top of the roll produces a shaking action which carries the finer pieces of coal in the feed rapidly through the crushing zone with a minimum of crushing, which partly accounts for the low percentage of fines produced in this type of crusher. The size and adjustment of the spring suspension to prevent the yielding of the springs for any except uncrushable materials, accounts for the minimum of oversize.

Bethlehem Section 30-in. I-beam girders form the side frame construction of these crushers as shown in the accompanying illustration. Cross members of heavy channel and angle plate are hot riveted to the girder beam side frames to form the rigid unbreakable unit construction. Electric steel bearing housings, shouldered into the side frames to take the shear and hot riveted in position, are fitted with interchangeable die cast bearing bushings, and thorough lubrication is provided by steamboat type grease cups. A segmental roll of special patented construction with no bolts through the crushing surface to weaken the segments, affords great strength and provides ready accessibility for changing when necessary.

The frame carries, in addition to the main roll shaft and the countershaft, a pivoted breaker plate which is



CROSS MEMBERS ARE HOT RIVETED TO THE GIRDER BEAM SIDE FRAMES

readily adjustable to and from the crushing roll to vary the size of product as needed.

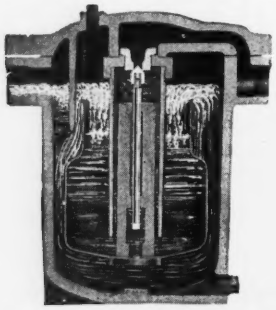
Supporting the breaker plate are heavy compression springs, designed to yield for the passage of tramp iron or other uncrushable materials, but which will not permit the passing of oversize coal through the choke feeding of the crusher. Besides the spring suspension of the breaker plate, a special safety device employing an ordinary steel bolt in hardened steel bushings prevents breakdowns in case of large iron in the feed. In this design the wearing parts are in plain sight and can be readily inspected.

Trap Designed With Quick Opening Valve

OPERATION OF the Eclipse Improved steam trap, as manufactured by the Illinois Engineering Co., Chicago, Ill., is explained as follows: in the filling or closed position the bucket is floating entirely surrounded by water and the valve is held to its seat by the operating pressure within the trap body and the buoyancy of the bucket. As more water enters the trap, it flows into the bucket until the buoyancy of the bucket is overcome and the bucket begins to sink. The valve is still held tightly against the seat by the pressure within the trap.

As the bucket sinks the water surrounding it pours into it and the completely filled bucket drops. When it has

fallen from 1 to 2 in., depending on the size of the trap, the shoulder on the center post, which is permanently attached to the bucket, strikes the head on the bottom of the valve stem. The momentum of the rapidly falling bucket produces a hammer blow, which instantly drives the two oil rings and an oil level indicating cup. The shaft nuts are designed to act as oil throwers and thus keep the oil in the bearings and the shaft sleeves are so designed as to keep water from creeping along the shaft and entering the bearings.



ACTION OF THE VALVE IS INSTANTANEOUS EVEN WHEN HANDLING SMALL QUANTITIES OF WATER

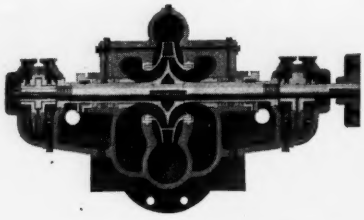


FIG. 1. BRONZE COMPANION WEARING RINGS ARE L SHAPED

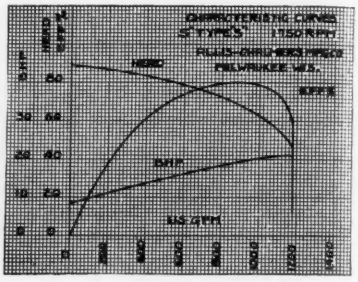


FIG. 2. EFFICIENCY OF 80 PER CENT WAS OBTAINED

valve from the seat a distance equal to the fall of the bucket.

This instantaneous opening of the valve eliminates wire drawing and it does not matter if only a small amount of water is trickling into the trap, the opening of the valve is as instantaneous as it is when the trap is handling its full capacity. Water from inside the bucket is discharged by the pressure within the trap through the wide open valve. As the valve has dropped from 1 to 2 in. away from the seat, there is an unobstructed flow through the seat port without eddy currents to decrease the discharge.

As the rising bucket carries the valve and stem up to the valve seat, the velocity of the water flowing through the seat will cause the valve to snap to the seat instantly closing the trap without wiredrawing so that the valve in this trap closes at a faster rate than the bucket rises. In the closed position, the lower end of the discharge tube is always water sealed so that this trap cannot blow steam. The cycle of operation is repeated from this point. Water entering the trap rises until it completely surrounds and overflows into the bucket again. The trap is so designed that it cannot become air bound.

Mechanical Improvement in New Pump

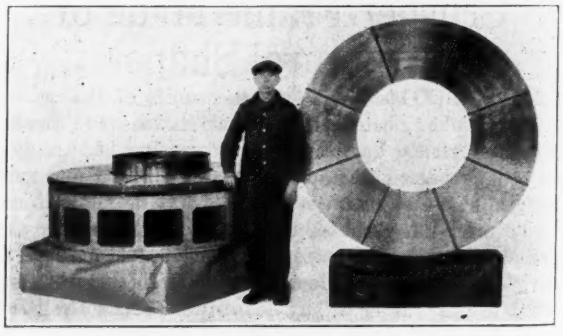
IN ADDITION TO its regular line of type "S" pumps the Allis-Chalmers Mfg. Co., Milwaukee, Wis., is now manufacturing a new line of low head pumps. They will be built in the smaller sizes and will be similar to the type "S" pumps excepting that there is incorporated in them a number of mechanical improvements. Their efficiency will be higher due to the elimination of a number of hydraulic losses.

Wearing rings are of bronze and are L shaped so as to reduce disturbance in the suction passage. The glands, which are split are of bronze and are drained to prevent water being thrown off or entering the bearings. The annealed steel shaft is provided with removable cast bronze sleeves which extend from the runner hub to the inside of the bearing housing. The water seal passages are integral with the upper half of the casing but can be arranged for outside seal when required. Each bearing is provided with

Figure 2 illustrates the performance of a 5-in. pump which showed 80 per cent efficiency when delivering 900 gal. per min. against a 68-ft. head. The efficiency was above 70 per cent for capacities from 520 to 1120 gal. per min.

A Million-Pound Thrust Bearing

PROGRESS in the design of hydroelectric generating equipment is reflected in the enormous thrust bearing shown in the accompanying photograph. This bearing is one of five made by the General Electric Co. for five, 54,000-kv.a. vertical shaft generators built by the Canadian General Electric Co. for installation in the Queenston station of the Ontario Hydro Electric Commission. The



ONE MILLION LB. SPRING THRUST BEARING FOR USE ON 54,000-KV.A. GENERATOR

bearing is 69 in. outside diameter, and is of the spring thrust type, being guaranteed to carry a load of 1,000,000 lb. at a normal rotating speed of 187.5 r.p.m. The load is made up of the revolving element of the turbine and generator, plus the downward thrust of the water. The bearing must also be able to operate at 10 r.p.m. for an hour or at a runaway speed of 350 r.p.m. for one hour.

This thrust bearing is installed at the top of the generator in an oil bath, cooled by water coils, and supports the weight of the revolving parts of the generator and tur-

bine, and the hydraulic thrust. The polished rubbing surface of the rotating ring of the thrust bearing is shown at the right. The babbit-faced stationary ring is assembled in its place, resting on 672 helical springs. The base ring under the springs is used to allow a sufficient depth of oil to accommodate the water cooling surrounding the bearing.

Meter Registers Volume of Coal Fed by Stoker

OPERATION of the Republic coal meter as manufactured by the Republic Flow Meters Co., Chicago, Ill., depends on the automatic recording of the product of the cross sectional area and the velocity of the layer of coal passing into the furnace, the meter therefore registering the volume of coal burned. The method by which this measurement is effected is as follows: the meter is attached to the driving mechanism of the grate in such a way that the speed of a ratchet wheel is varied in proportion to the grate travel.

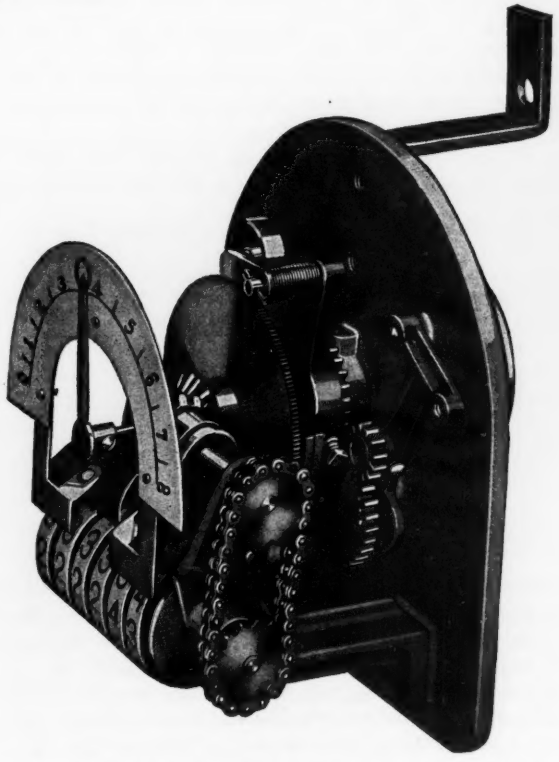


FIG. 1. SPEED OF THE METER RATCHET WHEEL VARIES IN PROPORTION TO THE GRATE TRAVEL

At the maximum gate height, the counter makes a complete revolution with the ratchet wheel, turning off 10 units. As the gate is lowered the motion is communicated to a cam which throws the two pawls out of contact with the ratchet wheel during a portion of a revolution so that the number of units turned off by the counter is decreased in proportion to the amount by which the gate is lowered.

Thus for an 8-in. maximum gate the counter turns off 10 units per revolution; at 4 in. gate height, 5 units per revolution and at 0 gate height the pawls are held from engaging the ratchet throughout a complete revolution so that the meter reading is zero. If a number of equal volumes of any coal are weighed, the variation in weight of the samples is extremely small; therefore by multiplying the revolutions of the counting wheel by a suitable constant, a highly accurate indication of the weight of coal burned will be obtained. If coal is bought and accepted on weight at a given moisture content, the volumetric coal meter gives an accurate record of the weight of coal consumed, because the record being based on measurement of volume, all errors due to change of moisture in the coal are eliminated.

FIG. 2. THIS METER MAY BE MOUNTED ON THE SIDE OF THE STOKER FRAME

To test this meter it is necessary to obtain only a bottomless box, volume of 20 cu. ft. This box is filled with coal and leveled at the top, so that, on the box being removed or lifted up, a pile of coal of 20 cu. ft. is ready for filling into the hopper. The coal in the hopper should be leveled off at the commencement and the time then taken until all the coal is used and the hopper filled again.

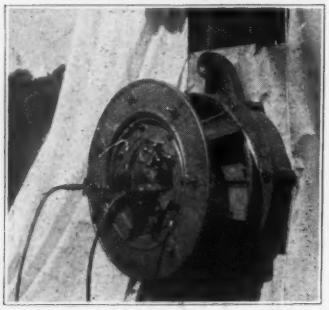
It is advisable to take readings of the meter, say every 5 min., and also at each change of grate speed or fire thickness. For equal volumes of coal consumed, the meter should register the same number of units irrespective of the fire thickness or speed and by dividing the volume of coal by the number of units registered a correct value of the unit, in cubic feet, will be determined. Occasional checks of the average weight of dry coal being burned will enable a user to know the actual weight of dry coal consumed.

A view of the meter with the protecting cover removed is shown in Fig. 1. The scale and pointer indicating the gate opening is shown immediately above the revolution counter, which is driven from the main shaft by a short chain belt. Figure 2 shows the meter in place on the side of the stoker frame. It can be installed on any type of chain grate stoker with practically no changes.

Combined Oil and Gas Burner for Power Purposes

RECENTLY THERE has been placed on the market by the Peabody Engineering Corp., New York, N. Y., a combined gas and oil burner for power purposes. This oil burner and air register are the standard Peabody-Fisher burner and Peabody air register. The gas burner is located between the furnace front and the air register and is so constructed that the gas enters the furnace in a thin conical sheet.

As the air entering through the register is rotating rapidly across the casting forming the face of the gas chamber an intimate mixture is obtained, which results in excellent combustion and maximum efficiency. It will be noted that the design of the burner is such that the change from one fuel to the other may be accomplished with no other mechanical operation than the opening and



GAS CHAMBER ON THIS BURNER IS AIR COOLED

closing of the proper valves. In fact, it is possible to burn both gas and oil simultaneously, a feature which facilitates the rapid change from one fuel to the other. The construction is such that when oil is being burned all the air for combustion passes over the gas chamber, thereby preventing overheating.

In tests conducted on a 500-hp. boiler fitted with three burners, capacities in excess of 300 per cent of builders' rating were obtained with either gas or oil. The capacity of the gas burner may be varied between 4000 and 20,000 cu. ft. per burner per hr.

Average results when operating on natural gas showed between 11 and 12 per cent CO_2 in the products of combustion with no CO and no smoke. The maximum CO_2 possible with the gas used was approximately 12 per cent. When oil was being burned, the average flue gas analysis showed 14.5 per cent CO_2, 1.5 per cent oxygen and no CO with practically no smoke.

Savings Result from Railway Electrification

ELECTRIC operation of the Chicago, Milwaukee & St. Paul Railway over the mountain ranges in Montana, Idaho and Washington has attracted considerable attention from those who are interested in the development and use of hydroelectric power as a substitute for steam power in railway transportation.

Mechanical features of the electrification and their advantages over steam operation are readily available by an inspection of the plant, but the vital inquiry made by investigators has been whether and to what extent there are economic advantages in electric operation versus steam operation. A careful study of the cost of operation under steam on the identical districts which were afterwards electrified has been made. It is based on an actual calculation of all the costs involved in both methods of operation and it reflects the relative costs of each.

Table given herewith shows for the years since the beginning of electrical operation the net savings from electrical operation, using for steam operation the actual costs for the last twelve months of such operation—adjusted to the costs obtaining in 1923; and for electrical operation, the actual costs as determined for the year 1923. The net savings shown are obtained by deducting from the savings in operating expenses the carrying charges of interest and depreciation on the additional investment required by the electrification which amounts to $15,625,739.00.

From this table it will be seen that for the year 1923, with its comparatively low tonnage, the net savings from electrical operation of the two sections amounted to $1,271,793.00. For the minimum tonnage so far experienced which was in the year 1921, the savings amounted to $671,014.00. The maximum tonnage so far experienced was in the year 1919. Had the section Othello to Tacoma been under electrical operation during that year the savings for the two sections would have amounted to $2,355,199.00.

No savings have been credited to electrical operation which are not susceptible of direct ascertainment, as for example, the possible increased revenue due to the release of equipment used in transportation of coal when these divisions were under steam operation; better utilization of freight equipment, due to faster movement; less wear and tear on road and equipment; less station expenses affected by the number of trains required to handle a given tonnage and increase in passenger revenue due to the attractiveness and greater comfort of travel.

These facts have been reported under the direction of W. W. K. Sparrow, vice-president, by Chester E. Oliphant, assistant to comptroller in charge of statistics, in consultation with R. Beeuwkes, electrical engineer, who had charge of the electrical installation.

VOLUME OF TRAFFIC AND SAVINGS RESULTING FROM ELECTRIFICATION

Years	Harlowton to Avery Electrical Operation began April and Nov. 1916		Othello to Tacoma Electrical Operation began March, 1920		All Electrified Sections	
	Volume of Traffic-Gross Ton Miles Frt. and Pass.	Net Savings by Electrification	Volume of Traffic-Gross Ton Miles Frt. and Pass	Net Savings by Electrification	Volume of Traffic-Gross Ton Miles Frt. and Pass	Net Savings by Electrification
1916	†1,639,054,000	†$ 1,098,166			1,639,054,000	$ 1,098,166
1917	2,677,097,000	1,641,369			2,677,097 000	1,641,369
1918	2,759,178,000	1,734,687			2,759,178,000	1,734,687
1919	2,894,063,000	1,888,037			2,894,063,000	1,888,037
1920	2,710,745,000	1,679,623	*691,674,000	* $249,003	3,402,419,000	1,928,626
1921	1,812,714,000	658,651	664,238,000	12,363	2,476,952,000	671,014
1922	2,109,868,000	996,485	734,121,000	403,301	2,843,989,000	1,099,786
1923	2,247,102,000	1,152,508	746,405,000	119,285	2,993,507,000	1,271,793
1924	2,129,426,000	1,018,721	* 691,476,000	47,808	2,820,902,000	1,066,529
Total		$11,868,247		$531,760		$12,400,007

†Tonnage and savings for 6½ months.
*Tonnage and savings for 9 months

News Notes

THE 48TH CONVENTION of the National Electric Light Association will be held in San Francisco, June 15 to 19, when it is expected that 5000 members and guests will be present. Special trains are being arranged; a Red Special to leave New York May 31 and make stops at points of interest in Colorado, New Mexico, Arizona and California, returning over a northern route after the convention with

stops at Portland and Canadian points; a Blue Special will leave New York June 10 and reach San Francisco the 15th; a Green Special will leave Chicago June 5 giving a 9-day trip through Canada, Washington and Oregon; an Orange Special will leave Chicago June 8 and make the trip in 6 days with stops at Seattle, Spokane and Portland. The details are in charge of Robert B. Grove, 130 East 15th St., New York, eastern traffic manager and Godfrey H. Atkin, 613 Marquette Bldg., Chicago, western traffic manager. Detail circulars have been sent out to members of the Association and may be obtained from the headquarters of the N. E. L. A., 29 West 39th St., New York. Hotel reservations should be made well in advance.

THE NATIONAL District Heating Association will hold its annual meeting at West Baden Springs May 17 to 22.

AT THE spring meeting of the American Institute of Electrical Engineers in St. Louis, April 13 to 17, papers will be presented on the following stations: Trenton Channel at Detroit, Cahokia at East St. Louis, Philo, Ohio, Weymouth at Boston, Crawford Ave. at Chicago. Other subjects will be, Use of Frequency Changers to Interconnect Systems, Short Circuits in Synchronous Machines, Self-Excited Synchronous Motors. The use of electricity in various industries will be discussed including Cement, Rubber and Glass.

AT THE TENTH annual meeting of the Board of the Engineering Foundation recently held in New York, Lewis Buckley Stilwell was elected chairman and Edward Dean Adams vice-chairman. Other officers elected were: Elmer A. Sperry, second vice-chairman; J. S. Langthorn, treasurer; Henry A. Lardner, assistant treasurer; Alfred D. Flinn, director and secretary.

On the board were elected from the United Engineering Societies, George H. Pegram of the A. S. C. E., J. Vipond Davies of the A. I. M. E., W. F. M. Goss of the A. S. M. E. and Bancroft Gherardi of the A. I. E. E. Also from the governing boards of the Founder Societies, Edward D. Adams, Robert Ridgway, Arthur L. Walker, H. M. Boylston, Arthur M. Greene, Jr., George A. Orrok, Gano Dunn and L. B. Stilwell. W. L. Saunders, president of the United Engineering Societies, is a member ex-officio and as members at large were chosen Elmer A. Sperry, Arthur D. Little and Charles F. Rand.

Plans are being studied for increase of the endowment of the Foundation which was established by Ambrose Swasey with a gift of $500,000 and supplemented by bequest of $50,000 under the will of Henry R. Towne, to $20,000,000. It is felt that the national engineering societies must have the benefit of a sustained and co-ordinated plan of research, if professional progress is to continue, and such research must be carried on by the organized engineering profession of the country.

DE LAVAL STEAM TURBINE Co., Trenton, N. J., announces that all products of that company and of the De Laval Separator Co., Poughkeepsie, N. Y., will in future be handled exclusively in New England by the Turbine Equipment Co., New England, Chamber of Commerce Building, 80 Federal St., Boston, Mass. F. R. C. Boyd, who for 15 years has been connected with the Power Equipment Co., is president of the new Turbine Equipment Co.

P. ALBERT POPPENHUSEN, formerly president of the Green Engineering Co., Ralph C. Acers and Earl A. Acers announce the formation of a partnership under the name of Acers-Poppenhusen with offices at 622 McCormick Building, Chicago. The new firm will represent the Engineer Co. "Proco" products and other companies manufacturing power plant equipment.

THE LUNKENHEIMER Co., of Cincinnati, Ohio announces that it will have an interesting display of valves, water columns, lubricators, oil pumps, whistles, etc., in both No. 104 at the "Informashow" given by the Purchasing Agents Association in Milwaukee Auditorium, Milwaukee, Wis., May 25—28, 1925. Of particular interest will be the new designs of Lunkenheimer Steel Gate Valves made in all sizes for 250, 400, 600 and 900-lb. working steam pressure.

STANDARD TURBINE CORP., Scio, N. Y., announces the following appointments of district representatives: J. F. Shouse & Co., 70 Kenyon Building, Louisville, Ky., and Bradley T. Johnson, 708 Mutual Building, Richmond, Va.

LYNN W. NONES has been appointed Eastern Sales Manager for the Diamond Power Specialty Corporation, in charge of the Atlantic Coast offices from Boston to Charlotte inclusive. His office is at 90 West St., New York.

JOHN J. GAFFEY, formerly with the Edison Electric Illuminating Co. of Boston and later assistant engineering manager for the Harry M. Hope Engineering Co., has recently joined the engineering force of the Station Betterment Division of Stone & Webster, Inc., Boston, Mass.

WM. R. VAN NORTWICK, who for the past 7 yr. has been district sales manager at New York for the Roto Co. of Hartford, Conn., has severed his connections with that company and has opened offices at 50 Church St., New York, for the sale of material to the same class of buyers.

PENNSYLVANIA CRUSHER Co. has recently appointed the Stratton-Cahoon Co., 809 McIntyre Building, Salt Lake City, Utah, as district agents for the sale of its product in the territory normally served from that city. Mr. Cahoon is a member of the A. S. M. E. and has had broad experience in handling problems of metal and coal mining as well as of power plants.

W. R. QUINN, former manager of the fuel oil department of the Combustion Engineering Corporation, New York, has been appointed Pacific Coast Agent of the company with headquarters in San Francisco. Mr. Quinn's territory will include the states of Washington, Oregon and California. The temporary western address is 1132 Shotwell St., San Francisco, Calif.

W. A. SHOUDY has recently been retained by the Bailey Meter Co. of Cleveland, O., as consulting engineer. Mr. Shoudy still retains his connections as advisory engineer to the Adirondack Power & Light Corp., Schenectady, and as Associate in Mechanical Engineering at Columbia University. He will also carry on his other consulting work with headquarters at 50 Church St., New York City.

DIAMOND SERVICE emblems have been presented by the American Engineering Co. of Philadelphia to 32 of its employes who have been with the company for a quarter century or more. Gold medals were presented to 275 other employes with records of 5 to 25 years' service. Heading the list of those receiving the diamond medals were two machinists with records of 46 and 45 yr. active service. Both are still employed daily in the shops of the company.

IMPROVEMENTS and additional equipment which will cost $50,000 are being made by the Mutual Ice Co. of Topeka, Kan. The old plant is steam driven, but the new

equipment which will be furnished by the York Mfg. Co., will occupy an adjoining new building and will be electrically driven. A 75-ton raw water tank is also being installed. The ultimate capacity of this plant will be 140 tons. This work has been started and the plant will be in operation about the first of April.

California Glucose Co., Los Angeles, Calif., is constructing a refining plant to produce glucose from wood refuse. A Stirling 100-hp. boiler is installed. H. C. Howard is chief engineer. It is reported that this will be the first plant of its kind in the U. S. although there are three in Germany.

Installation has just been completed in the Municipal Water Department of Whittier, Calif., of a 5-stage Curtis 625-kw. turbine, Worthington condenser and centrifugal pump, a 120-hp. Bonus-Freeman water-tube boiler, which is the fourth unit, and a General Electric switchboard. The installation has been supervised and directed by A. L. Underwood, superintendent, and E. A. Maynard, chief engineer of the department.

Orders for two 35,000-kw., 50-cycle turbine generators and two 1000-kw., 3300-v., 50-cycle house turbines have been placed with the International General Electric Co. by the Hayakawa Electric Power Co. of Kawasaki, Japan. The equipment represents the largest complete units ever sold by any company for export. The Hayakawa Co. will use the apparatus in parallel with its hydroelectric station in the Hamamatsu district for furnishing power to Tokyo.

Books and Catalogs

Substation Operation, by Edwin Kurtz; 261 pages, 5½ by 8 in., cloth; first edition; New York, N. Y., 1924. Price, $2.50.

This is an elementary textbook intended for men engaged in actual substation operation who wish to acquire a thorough knowledge of principles and methods. It will aid them in the study of wiring, in acquiring the names of machines and auxiliary apparatus and in learning their functions. It also treats of testing circuits, care of safety equipment, principles of accident prevention, first aid and the keeping of records.

It is not expected that anyone can become an expert operator by study of this book alone; but to the man who is in contact with actual substation operation, it should be an effective help. The presentation of electrical theory is confined to a few fundamental ideas and the explanations of principles of operation of machines and auxiliary apparatus are stated as simply as possible. The discussions on operating procedure are quite complete, more so in fact than those givers in the usual instruction books issued.

An interesting feature of the book is its hydraulic analogies used in explaining the principles involved in the operation of various pieces of electrical equipment. These are accompanied by simple line diagrams and should be of considerable help to the man wishing to gain a knowledge of fundamentals.

Engineering Experiment Station of the University of Illinois has just issued circular No. 12 entitled "The Analysis of Fuel Gas" which gives a description of the apparatus developed by the University for the purposes of analyzing fuel gas and also contains a synopsis of the methods which are best adapted to this type of apparatus. A comprehensive review of methods to be used with other types of apparatus is included in the appendix of the circular.

Marion Machine, Foundry & Supply Co of Marion, Ind., has issued a new 24-page catalog, No. 50-R, describing the Marion line of soot blowers. This is an attractively illustrated booklet showing in detail the principles and methods of operation of these soot blowers. They are made for all types of water-tube and fire-tube boilers. For the extremely high temperatures which occur in some passes of boilers, a special Hi-Temperature Alloy element is available. This withstands high temperatures and is non-corrosive.

Yarnall-Waring Co. has just issued folder No. B-411 showing the different types of blowoff valves which this company manufactures for pressure ranges from 100 to 650 lb. per sq. in

Bulletin No. 64, just issued by the Bonnot Co. of Canton, Ohio, describes the Bonnot Unit-Air Ball Mill. This is a coal pulverizing unit for particular application to boiler firing.

McAleenan water-tube boilers are described in catalog No. 4 just issued by the McAleenan Corp. of Pittsburgh, Pa. This catalog discusses the characteristics of inclined and horizontal type boilers and contains sections on boiler settings and boilers for the utilization of waste heat.

Bulletin No. 1582 has just been issued by the Hisey-Wolf Machine Co. of Cincinnati, Ohio, describing four new types of motor-driven combination grinding and buffing machines. These are built in sizes from ½ to 10 hp. and are adaptable for use with alternating and direct current.

"Ten Years' Achievements in Water Treatment, Filtration and Softening" is the title of a book just issued by the Paige-Jones Chemical Co. of Hammond, Ind. This book gives some sidelights on what the company has contributed to the development of water treatment with particular emphasis on pioneer work.

"Kerr Turbines for Generator Drive" are described in Catalog "H" just issued by the Elliott Co., Turbine Sales Dept., Wellsville, N. Y. This catalog describes in detail the constructional features of Kerr turbines and gives sectional views of bleeder turbines, automatic bleeder mechanism, low and mixed pressure turbines and reduction gears.

Speed Reducers of both the spur gear and worm gear types are described in a leaflet being distributed by Foote Bros. Gear & Machine Co., Chicago, Ill. Speed reduction ratios range from 4 to 1 to 320 to 1 on spur gear reducers, or up to 50,000 to 1 in combinations with worm gear reducers. Power transmission ranges with these units from fractional horsepower up to 150 hp.

Smoot Engineering Corp. of New York City has just issued bulletins Nos. 16 and 17 describing the combustion control system which this company manufactures. In this system the master controller is the central point of control and all changes of steam pressure are transformed proportionately to air loading pressures operating regulators, controlling fuel supply, air volume and draft.

"Electric equipment for Cranes" is a General Electric bulletin, No. 48,732, recently issued. This is an attractive, 35-page leaflet, well illustrated with photographs, diagrams, tables and charts. It discusses the subject thoroughly, with particular reference to crane motors and control, brakes, etc. Information is given on operating characteristics, and types of standard motors are listed, together with other data.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

The Final Test

Life is a laboratory, progress a series of tests. Only recession has no trials.

Improvements in methods and extensions of practice in trying out things is the measure of the advancement of civilization itself. It finds new forms and proves them; it is a constant process of progress.

Modern industry dates its period of dominance over older forms of organization from the time it began to make sure by test of its methods, processes and products, for authority is ever conceded to men and institutions that are sure of their ground.

Certainties are what we demand in life, for uncertainty is waste of life itself.

Laboratories of today are dealing with paints and oils for a smokestack or a boiler casing; metals and their alloys for a shaft, a bearing or a valve part; woods for doors and woods for shipping crates. Thousands of accepted products, familiar to everyone, are constantly being studied to make their service still more certain and economical.

This great modern development has brought science, invention and the genius of discovery directly to the immediate service of the people.

But the power that has revealed the possibilities, furnished the funds and offered the incentive to command all this activity and to bring together the men of science, business and industry to work out these vast everyday problems of life is advertising.

Because of advertising and as a result of its workings throughout the entire social, financial and industrial structure of a people, a higher test and more difficult trial prevails than all those made in laboratories and testing rooms.

It is at once the test of all other tests and at the same time a test that transcends them all, because it includes tests that no manufacturer can have made of his product in shop, laboratory or out in actual service.

This is the test of a product which tells whether or not it may be successfully advertised.

No one man nor any single issue of this publication could show how this test is applied and how it works out for the benefit of the people. Only the briefest outline may be given.

Advertising commands attention and interest. It is an inborn trait of human nature to increase the severity of its tests in proportion to its interest.

Publicity is indeed pitiless. For example, a man may be a pretty good sort until he runs for office or attains fame in some direction. Then his most trivial act is magnified all out of proportion to its significance when he was an ordinary citizen.

To advertise a product or service makes it like a man running for office. It is focused in the spotlight. It is literally X-rayed to find its every possible weakness. More is expected of it than of any similar product or service that is not advertised.

This well-known fact forces advertisers to be extremely rigid in their standards of truth; to weigh the meaning of words; to exercise utmost vigilance in stating their case.

But the advertisement is only a visible expression in words about the product. Greater than this is the tremendous force of advertising that reaches back from this printed message; which constantly intensifies every test, raises standards and keeps on his toes every man whose work contributes to an advertised product.

Advertising has become more and more a definite thing, a controllable force, subject to development, direction and application, much the same as mechanical power.

It is this control and development that engages advertising men whether on this publication or elsewhere. It is this activity that is quite as unknown to the general public, who see only the advertisements, as the power house is unknown to the people who use light and power.

In the power plant field, many products have been built, tested in the shop, operated in a power plant and yet not offered generally to the field.

Advertisements are offered for these pages that do not appear even though the product itself seems to be meritorious and adapted to the service for which it is intended.

Manufacturing processes must be perfected; financial responsibility established; sales methods must be sound and economical; knowledge of the field acquired—all these and many more are necessary factors to complete the service of any product that can be successfully advertised.

In the highly specialized fields of industry such as the field in which this publication serves, every test must be carried to a fine point, every principle applied with great exactness.

Happily the very conditions that require these high standards make more possible their fulfillment.

Every advertisement in these pages is read by men with common professional interests, training and work, men facing similar problems and having high standards of expectation as to what they read and what they shall buy.

In consequence, the products advertised here are not up for test, but have been tested—tested to an extent that rarely, if ever, obtains in any field outside of the great, basic industries of the country.

They are proved in a way few products ever need to be proved except where a single unit involves safety, security and service to hundreds and thousands of people, as in the power plant field.

They have passed the final test before they are here advertised.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR CHAMBERS.
Hercules Float Wks., Springfield, Mass.

AIR COMPRESSORS.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Steam Pump Co., Battle Creek, Mich.
American Well Works, The, Aurora, Ill.
Dean Bros. Co., Indianapolis.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Murray Iron Works Co., Burlington, Iowa
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros. Co., Chicago, Ill.

AIR WASHERS.
Badger & Sons Co., E. B., Boston, Mass.
Cooling Tower Co., Inc., The, New York.

ALARMS, HIGH AND LOW WATER
Hills-McCanna Co., Chicago, Ill.
Huyette Co., Inc., The Paul B., Philadelphia.
Northern Equipment Co., Erie.
Reliance Gauge Column Co., Cleveland, Ohio

ARCHES, BOILER AND COMBUSTION.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Brady Conveyors Corp., Chicago.
Detrick Co., M. H., Chicago.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Hofft Co., The M. A., Indianapolis, Ind.
Lavino & Co., E. J. Philadelphia.
Liptak Fire Brick Arch Co., Mexico, Mo.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

ASH AND COAL BINS.
Frederick Iron & Steel Co., Frederick, Md.

ASH BIN GATES AND DOORS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Beaumont Mfg. Co., Philadelphia, Pa.
Brady Conveyors Corp., Chicago.

ASH CONVEYING SYSTEMS.
Beaumont Mfg. Co., Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
Link-Belt Company, Chicago.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
United Conveyors Corp., Chicago, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

ASH HANDLING SYSTEMS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
United Conveyors Corp., Chicago, Ill.

ASH TANKS.
United Conveyors Corp., Chicago.

BAROMETERS.
Taylor Instrument Co's., Rochester, N. Y.

BEARING METAL.
Strong, Carlisle & Hammond Co., Cleveland, Ohio.

BEARINGS.
National Tube Co., Pittsburgh.

BELT CONVEYORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

BELT DRESSING.
Cling-Surface Co., Buffalo, N. Y.
Dixon Crucible Co., Jos., Jersey City, N. J.
Standard Oil Co., (Indiana), Chicago, Ill.
Stephenson Mfg. Co., Albany.

BELT LACING.
Bristol Co., The, Waterbury.
Flexible Steel Lacing Co., Chicago.

BELTING.
New York Belting & P'k'g. Co., New York.
Quaker City Rubber Co., Phila.
United States Rubber Co., New York, N. Y.
Voorhees Rubber Mfg. Co., Jersey City, N. J.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.

BLOWERS, FAN & FURNACE.
Carling Turbine Blower Co., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Terry Steam Turbine Co., Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia.
King Refractories Co., Inc., Buffalo, N. Y.
Lavino & Co., E. J. Philadelphia.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

BOILER SETTINGS.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 158

BLOWERS, FORCED DRAFT.
Sturtevant Co., B. F., Hyde Park, Mass.

BLOWERS, PORTABLE
Sturtevant Co., B. F., Hyde Park, Mass.

BLOWERS, STEAM.
Schutte & Koerting Co., Phila.

BLOWERS, TUBE.
Bayer Co., The, St. Louis, Mo.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Sherwood Mfg. Co., Buffalo, N. Y.
Vulcan Soot Cleaner Co., Du Bois, Pa.
Webster, Howard J., Philadelphia, Pa.

BLOWERS, TURBINE.
Carling Turbine Blower Co., Worcester, Mass.
Moore Steam Turbine Corp., Wellsville, N. Y.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLES.
Betson Plastic Fire Brick Co., Rome, N. Y.
Johns-Manville, Inc., New York.
King Refractories Co., Inc., Buffalo, N. Y.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Specialties Co., Inc., New York.

BOILER CAP CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.

BOILER COMPOUND.
Botfield Refractories Co., Philadelphia, Pa.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
McLeod & Henry Co., Troy, N. Y.
Paige & Jones Chemical Co., Inc., New York.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER FEED WATER PURIFYING APPARATUS.
Griscom-Russell Co., New York.
Paige & Jones Chemical Co., Inc., New York.
Permutit Co., New York, N. Y.
Power Plant Specialty Co., Chicago, Ill.

BOILER FRONTS.
McLeod & Henry Co., Troy, N. Y.
King Refractories Co., Inc., Buffalo, N. Y.
Lavino & Co., E. J. Philadelphia.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.
Webster, Howard J., Philadelphia, Pa.

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBE CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh.
Pierce Co., The Wm. B., Buffalo, N. Y.
Roto Co., The, Hartford, Conn.

BOILER TUBES.
Babcock & Wilcox Tube Co., The, Beaver Falls, Pa.
Murray Iron Works Co., Burlington, Iowa.
National Tube Co., Pittsburgh.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Botfield Refractories Co., Philadelphia, Pa.
Johns-Manville, Inc., New York.

BOILERS.
Babcock & Wilcox Co., N. Y.
Badenhausen Corporation, Philadelphia, Pa.
Bethlehem Shipbuilding Corp., Bethlehem, Pa.
Casey-Hedges Co., The, Chattanooga, Tenn.
Edge Moor Iron Co., Edge Moor,
Erie City Iron Works, Erie, Pa.
Kingsford Fdry. & Mach. Wks., Oswego, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Union Iron Wks., Erie, Pa.
Vilter Mfg. Co., Milwaukee, Wis.
Webster, Howard J., Philadelphia, Pa.
Wickes Boiler Co., Saginaw,

BOOKS AND SCHOOLS.
McGraw-Hill Book Co., Inc., New York, N. Y.
Sweet's Catalogue Service, Inc., New York, N. Y.

BREECHINGS.
Littleford Bros., Cincinnati, O.

BRICKS, FURNACE LINING.
Norton Co., Worcester, Mass.

BRUSHES, DYNAMO AND MOTOR.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Link-Belt Company, Chicago.
Webster Mfg. Co., The, Chicago.

BUCKETS, CLAMSHELL.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.

CAR DUMPERS.
Wellman - Seaver - Morgan Co., The, Cleveland, O.

CARRIERS, PIVOTED BUCKET.
Webster Mfg. Co., The, Chicago.

CASTINGS.
Fuller-Lehigh Co., Fullerton, Pa.
Hills-McCanna Co., Chicago, Ill.
Neemes Fdry. Inc., Troy, N. Y.

CEMENT, ASBESTOS.
New York Belting & P'k'g. Co., New York.

CEMENT, FURNACE.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh.
King Refractories Co., Inc., Buffalo.
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Plibrico Jointless Firebrick Co., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

CEMENT, HIGH TEMPERATURE.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
King Refractories Co., Inc., Buffalo, N. Y.
Lavino & Co., E. J. Philadelphia.
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago.
Quigley Furnace Specialties Co., Inc., New York.

CEMENT, IRON.
Smooth-On Mfg. Co., Jersey City, N. J.

CHAIN WHEELS.
Babbitt Steam Specialty Co., New Bedford, Mass.

CHAINS, DRIVE.
Link-Belt Company, Chicago.
Morse Chain Co., Ithaca, N. Y.

CHIMNEYS.
American Chimney Corp., New York,

CLEANERS, BOILER TUBE.
General Specialty Co., The, Buffalo, N. Y.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh, Pa.
Pierce Co., The Wm. B., Buffalo.
Roto Co., The, Hartford, Conn.
Sherwood Mfg. Co., Buffalo, N. Y.

CLEANING COMPOUND.
Dearborn Chemical Co., Chicago, Ill.

COAL AND ASH-HANDLING MACHINERY.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Beaumont Mfg. Co., Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of America, Chicago, Ill.